THE MAY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

NEW BOOKS OF SCIENTIFIC INTEREST

The Physics of Electron Tubes. L. R. KOLLER. xiii + 205 pp. Illustrated. $3.00. McGraw-Hill.

A presentation of the fundamental physical phenomena involved in the operation of electron tubes for individuals with no special training in electronics. Emphasis has been placed on what goes on within the tube and not upon external circuits.

Theoretical Physics. Vol. II. W. WILSON. xi + 315 pp. $5.75. Dutton.

This is a continuation of Volume I and is subtitled "Electro-magnetism and Optics, Maxwell-Lorenz." It is based upon the author's lectures at the University of London. Especial attention is given to units and to the dimensions of physical quantities.

Principles of Mechanism. A. VALLANCE and M. E. FARRIS. vii + 335 pp. Illustrated. $3.50. Macmillan.

This text-book for engineering students is a compilation of the material used in courses in mechanism. The aim of the work is to study the analysis of the motions of machine and engine parts essential to good design.

Colour Science. The late WILHELM OSTWALD. Part I, **Colour Theory and Colour Standardisation.** xviii + 141 pp. Part II, **Applied Colour Science.** xii + 173 pp. Winsor and Newton (London).

A handbook of color for advanced student in schools, colleges and the various arts, crafts and industries depending on the use of color. It is an authorized translation, with an introduction and notes by J. Scott Taylor. Although a physicist, Ostwald has approached the study from the psychological point of view. The second volume is divided into the three sections: Colour measurement; Colour in the physico-chemical sphere; and Colour in the psycho-physical sphere. Elaborate color charts, composed partly of cloth, are included.

The Chemical Formulary. Vol. I. H. BENNETT, Editor-in-Chief. x + 595 pp. $6.00. Chemical Formulary Co.

This reference book presents a compilation of formulae for the chemical compounding of adhesives, cosmetics, insecticides, food products, paint materials and many other products. Most of the information can be understood by laymen.

The Physical Properties of Lumber. G. F. IVEY. x + 263 pp. Illustrated. $2.00. Southern Publishing Co.

Grading, weight, hardness, shrinkage, strength, elasticity and production of lumber are discussed. Descriptions of the principal species of trees and their use as lumber occupy about two thirds of the book.

Technics and Civilization. LEWIS MUMFORD. xi + 495 pp. Illustrated. $4.50. Harcourt, Brace.

In this study of the rise and development of technics the author attempts to explain the origin of the machine and to trace its effects upon civilization. A list of inventions, bibliography and index are appended.

The Vitamins in Health and Disease. BARNETT SURE. xiv + 206 pp. $2.00. Williams and Wilkins.

This book tells, in non-technical language, of the ills which have been definitely traced to vitamin deficiency and how to avoid them. The author suggests it as a college text in nutrition for students without training in chemistry.

Mental Hygiene in the Community. CLARA BASSETT. 394 pp. $3.50. Macmillan.

This study of the relation of mental hygiene to the problems of community life, presented by a consultant in psychiatric social work, defines mental hygiene and analyzes its value as a factor in achieving a healthier community life.

Elements of Biology. JAMES W. BUCHANAN. xi + 478 pp. Illustrated. $3.00. Harpers.

A basic text-book in general biology for students in colleges of liberal arts presenting the fundamental concepts of the subject from the modern point of view. Emphasis has been placed on the physiological aspects of biological phenomena, although a chapter on taxonomy has been included.

Songs of Wild Birds. ALBERT R. BRAND. 91 pp. Illustrated. $2.00. Thomas Nelson.

Thirty-five wild birds of the eastern United States and their songs are described. Two double-faced nonbreakable phonograph records of the bird songs are provided. The author is associate in ornithology at the American Museum of Natural History.

Gardens and Gardening. F. A. MERCER, Editor. 128 pp. Illustrated. $4.50. Studio Publications.

The 1934 Studio Garden Annual begins with a general survey of gardens in many countries, with many photographs, and then proceeds to discuss different aspects of garden technique in a more specialized, detailed and practical manner.

An Introduction to Physical Education. EUGENE W. NIXON and FREDERICK W. COZENS. 262 pp. $2.50. W. B. Saunders.

This text-book and guide for students and teachers of physical education has been divided into three parts: Philosophy and principles of physical education; significant problems in physical education; and the professional outlook in physical education.

THE SCIENTIFIC MONTHLY

MAY, 1934

THE FAITH OF REVERENT SCIENCE[1]

By the Late WILLIAM MORRIS DAVIS

AT THE TIME OF HIS DEATH EMERITUS PROFESSOR OF PHYSICAL GEOGRAPHY AT HARVARD UNIVERSITY

PART I

Outline. The object of this address is, first, to direct attention to the enormous service of science in liberating our minds from their century-long subjection to ancient dogmas, thus enabling us freely to enjoy the modern understanding of the world and of our place in it; and second, to consider certain responsibilities that are placed upon us in consequence of our liberation. With this object the contents of the address are as follows: It will begin with an introductory statement concerning two great products of the human mind—religion and science. Then will follow several retrospects, the first of which will recall the harmonious relation existing between primitive religion and primitive science among primitive peoples; the second will touch upon the unhappy conflict which arose between struggling science and theologically dominated religion in the later centuries of European history; and, after a brief interlude, the third retrospect will tell of the victory of science over various theological elements of our religion in a recent era which might well, for that reason *alone,* be called the Victorian. In this short review it will not be so much the events of the several retrospects as the state of mind behind the events that we shall try to consider.

Then will follow a sketch of the actively growing reconciliation of Christian theology with modern science, which has so fortunately occupied the short period from the Victorian era to the present. After that, an outline will be given of the faith toward which multitudes of our population, who have become more or less conscious of the reconciliation just mentioned, are now advancing. There will then come some reflections on our new responsibilities in consequence of that reconciliation, and also a prognostication of the manner in which our new responsibilities can best be met, this being the main theme of my address.

Introduction. Two of the greatest products of the human mind are the various systems of faith known as religions and the various bodies of knowledge known as sciences. Both have slowly evolved from ancient and simple beginnings to their present complications; and the evolution of both appears to have been largely guided by outstanding leaders who have arisen from time to time in the two lines of thought. Religion is believed to have begun as a form

[1] The second Hector Maiben lecture presented at the meetings of the American Association for the Advancement of Science at Cambridge, Massachusetts, on December 28. Professor Davis died on February 5 in his eighty-fourth year. An appreciation by Professor John P. Buwalda, with a portrait, was printed in THE SCIENTIFIC MONTHLY for April.

of magic, in which the "medicine man" or shaman used certain incantations to compel the "powers" to act as he wished them to act. Later, when the powers were personified as deities, they were no longer compelled by incantations but implored by prayers and sacrifices to act as their priests wished. In its simpler stages religion was largely concerned with relations of humanity to the gods; in its more advanced stages it comes to be much concerned also with the relation of human beings to one another. Thus we have the division of religion into its two parts, theology and ethics. Science must have begun among primitive peoples as simple observation, soon followed by elementary induction; but, as we now know it, science involves mental processes far too elaborate for primitive peoples. Like religion, it must have had a gradual beginning, and the beginning may have been as little like its present state as a seed is like a full-grown plant.

At present religions are systems of faith which their devotees believe have been made known in smaller or greater part by inspiration or revelation from the supernatural world. Sciences are, on the other hand, bodies of demonstrable knowledge regarding the natural world, as far as it is open to observation and to inference based on observation. Both these lines of thought have come to be largely under the direction of two groups of specialists; the priesthoods of the churches and the professorhoods of the universities; but the priesthoods are supplemented by learned men among the laity, and the professorhoods are reënforced by many skilled experts in the arts and the industries.

Before going farther, let me repeat a significant word—the word "human." I have said the systems of religious faith and the bodies of scientific knowledge are both the products of the human mind. That rejects supernatural revelation on which the followers of various religions believe them to be based. This statement may arouse dissent. Yet every one present will doubtless agree that all the sciences are purely human achievements. Most of those present will, I presume, accept also the purely human origin of the ruder religions of primitive humanity, perhaps including the hard religion of fear and punishment that was developed several thousand years ago among the barbarous Israelites. Many of those present may perhaps accept the wholly human origin of all the modern religions of to-day, excepting Christianity. And some may believe, as I do, that all religions, ancient and modern, including Christianity, are, like all the sciences, wholly of human origin. The grounds for this belief will be presented in the review of the recent reconciliation of Christian theology and science.

First Retrospect. Our first retrospect is brief. It recalls the harmonious relation between the crude science and the rude religion of primitive peoples. If scientific explanation of natural phenomena is there attempted it is often wrong, largely because it is so commonly given a supernatural nature. For example, dwellers in arid regions do not ascribe the rains of their thunderstorms to the adiabatic cooling of ascending air currents, but to their rain god, to whom they therefore address prayers when rain is wanted. The priesthood has charge of such supernatural beliefs, and they develop them in accord with the rest of their religious system. Conflict between their science and their religion is thus avoided.

Second Retrospect. Our second retrospect deals summarily with the later European centuries. We there find at first one and later several priesthoods, each in charge of its own phase of Christianity. Let us remember that, as then taught, Christianity was little concerned with the simple ethical principles

preached by its founder; principles phrased in easily understood words and addressed to an uneducated population. Christianity of the Middle Ages and the next following centuries was largely concerned with highly theological creeds which had been adopted in earlier centuries by majority votes of humanly, not to say politically appointed delegates at the councils of a well-organized and dominant church. Moreover, some of the councils were held at times of violent metaphysical disputes within the church; in one instance about a matter so recondite as the difference expressed, as Gibbon puts it, by the vowel of homoouzion and the diphthong of homoiouzion.

It is truly singular that a great religion should be, not only then but almost to this present day, so largely concerned with the theology of complicated, majority-vote creeds rather than with the simple ethics of its founder; but such is clearly the case.[2] The explanation of this singularity is clear also; it is the result of ecclasiastical organization; and it has been through such organization that the peoples of Europe and of European stock have been so long held subject to a theologically dominated religion. And here let me state a very curious feature of that subjection. By reason of a strange concatenation of ancient events, the theological doctrines which have so long dominated European Christianity are the outgrowth of a series of crude, superstitious beliefs which originated several thousand years ago among the barbarous, ignorant, credulous peoples of southwestern Asia; a body of beliefs which was recorded, in the form commonly known to us, by a people who believed themselves "chosen" by their god from among all other peoples; a body of beliefs which was introduced into Europe in close association with a new gospel which that "chosen" people rejected, a rejection which later caused three centuries of cruel persecution. And yet we—that is, all peoples of European stock—adopted both the old beliefs and the new gospel as the infallible "Word of God." Does history record anything more extraordinary?

Is there any wonder that a conflict arose when European mentality began to assert itself? Those old beliefs, especially the cosmological myth standing at their beginning, were fitting enough for the race which, in the childhood of humanity, invented them. But how impossible it was that they should accord with the discoveries of science made by another race in another region under altogether different conditions!

Specifically, it was the heliocentric arrangement of the solar system, an old Greek view revived by Copernicus, which conflicted with the traditional position of a fixed earth in a geocentric system, as revealed in Genesis. Science, more or less aware of our many ignorances, tried by observation and reflection to establish a safe beginning of knowledge. Theology insisted that a finality of knowledge had been given us on this, as on so many other subjects. Hence the Copernican system was condemned as heretical, and under the strongly organized Christian priesthood of that time, heretics had a terrible time of it. Even the protesting Luther said: "The fool"—Copernicus—"wishes to reverse the entire science of astronomy, but sacred Scripture tells us that Joshua commanded the sun to stand still, and not the earth."

Let it here be emphasized that the real significance of the conflict which thus arose did not lie so much in the difference of the two systems of astronomy as in the unlikeness of the reasons for adopting them and in the unlikeness of

[2] Edwin Hatch, "The Influence of Greek Ideas and Usages upon the Christian Church" (The Hibbert Lectures, 1888). Ed. by A. M. Fairbairn, London and Edinburgh, Williams and Norgate, 1890.

the minds which accepted those reasons. From the theological point of view, the relation of earth and sun was not to be studied; it was infallibly known and settled by revelation. From a scientific point of view that relation was, like any other problem, open to unprejudiced discussion. The scientific mind would be inclined to say that, if the revealed relation of earth and sun were true, it could only be confirmed by unprejudiced investigation, while if it were not true it would be thereby corrected. But the theological mind refused to take the risk of alternative conclusions, and it therefore opposed all such investigation. Thus the right of the human mind to think was infringed upon, its practise in thinking was lessened, and its progress in the difficult art of learning how to think correctly was retarded. In our freedom to-day, when investigation is aided and encouraged in every direction, we can hardly imagine how persistently it was hampered and opposed in earlier centuries. Experimentation in physics and chemistry was frowned upon if not suppressed. Philological study was retarded by the belief that Hebrew, as spoken by Adam and Eve, as well as by Jehovah and the Serpent, in the Garden of Eden, was the original language of mankind. The humane care and cure of the insane was long delayed by the theological belief that insanity was due to "demoniacal possession." Even in the nineteenth century the use of an anesthetic in childbirth was opposed by the orthodox on the ground that it avoided "part of the primeval curse upon women," although it was at the same time ingeniously defended by pointing out that in preparation for "the first surgical operation ever performed"—that of taking a rib from Adam's side for the creation of Eve—a "deep sleep" was caused to fall upon the rib-loser.

All this opposition was epitomized centuries earlier; for when the Franciscan friar, Roger Bacon, wished to increase his knowledge by experimentation instead of by deducing all truth from sacred texts, he was attacked on the ground that "he did not believe that philosophy had become complete and that nothing more was to be learned." He was forbidden by the "general" of his order to lecture at Oxford; his brilliant studies of the refraction of light in the production of rainbows were condemned because the rainbow was theologically believed not to be a result of natural laws but a "sign" supernaturally placed in the heavens to assure mankind that another universal deluge was not to be feared. And in his old age Bacon was imprisoned for fourteen years because he was "dangerous." How glorious is our mental freedom compared to the enslavement of those earlier times! When we realize the long struggle that our freedom cost our predecessors, should we not strive to use it worthily?

Let me close this retrospect by acknowledging my deep indebtedness to White's two masterly volumes on "The Warfare of Science and Theology in Christendom," from which the above statements are taken, and in which one may find the following general conclusion: "The establishment of Christianity . . . arrested the normal development of the physical sciences for over fifteen hundred years" (vol. 1, p. 375). Those who have not read this great work should do so without delay, for it will teach them many wonderful stories; for example, that of John Wesley, surely a man of no mean intellect, who nevertheless believed that spiders did not eat flies until after Adam sinned.

Interlude. Several eventful centuries elapse between our second and third retrospects, during which the spirit of scientific rationalism gained much strength; for this was an era in which the minds of Europeans were slowly

learning to work more and more independently of preconceived opinions. With this growth of rationalism the number of heretical unbelievers—that is, unbelievers of various theological complications—greatly increased. But that same era witnessed also some growth of the spirit of Christian ethics, and although unbelievers were still branded as heretics, the branding was only verbal; they were no longer burned at the stake.

This era witnessed another manifestation of mental independence in the multiplication of religious sects, each one having its peculiar creed or organization based on Biblical texts which were still taken as the "Word of God," and elaborated in the mind of some able leader. At the risk of repeating what is already well known to some of you, I wish to give a few examples of the theological doctrines which were then still in force, in order that you may contrast them with the relative freedom of to-day. Nearly 300 years ago a famous "Confession of Faith" was formulated by a body of 150 learned and godly men who were summoned by an act of Cromwell's Long Parliament and were in close consultation for five years. Two articles of this confession may be here cited. One of them sets forth again the old doctrine of original sin, which many a piously taught child of earlier times than now learned in its condensed, rhythmical form: "In Adam's fall we sinnèd all"; but which, phrased in more sententious form by those godly men, is as follows: "From this original corruption"—that is, from Adam's sin—"whereby we are utterly indisposed, disabled and made opposed to all good and wholly inclined to all evil, do proceed all actual transgressions." There can be no question that this extraordinary article was authentically based on Scriptural texts; but there can also be no question that its doctrine is now so completely opposed by the teachings of evolutionary ethnology as to be scientifically absurd. Can there be a more striking example of the manner in which ancient error was perpetuated?

But that is not all. That now absurd article was supplemented by another which taught the perdition of most of the human race, because of a baneful clause found near the end of the Gospel of St. Mark but not in the other Gospels; a clause now suspected by competent students to be spurious, for it is given as a saying of Jesus in spite of its violent contradiction of the spirit of his more authentic teachings; a clause which "has cost the world more innocent blood than any other" (White, II, 387); a little clause of only eight words, reading: "And he that believeth not shall be damned" (Mark 16: 16). Chiefly upon that clause a monstrous conclusion was stated in another article of the abovementioned "Confession of Faith," as follows: "No men, not professing the Christian religion, can be saved in any way whatsoever than by becoming Christians, be they ever so diligent to frame their lives according to the light of nature and the law of the religion that they profess; and to assert and maintain that they may be is very pernicious and to be detested."

Had Jesus been present when that detestable article was adopted—he who taught us: "Be ye therefore merciful, as your Father also is merciful"—would he not have said once more: "Father, forgive them, for they know not what they do." Or if that article had been found in a distant land, expressing the will of some pagan Juggernaut, would not all godly Christians have joined in condemning it as altogether opposed to the will of a loving and forgiving Father in Heaven? And yet, under abject submission to ancient myths and to very fallible records of later date, those 150 earnest, devoted, conscientious men compelled themselves to believe that monstrous

theological doctrine, with its imagined alternatives of perdition and salvation!

Third Retrospect. The conflict between the theological elements of Christianity and science reached a climax in the Victorian era, to which our third retrospect is directed, because science had by that time gained immensely in strength and independence. Not long before that era opened, the past history and the future continuity of the earth had been shown to be vastly longer than the Bible taught. As the Scotch geologist, Hutton, put it: "In the history of the earth there is no trace of a beginning and no prospect of an end." Then, shortly after the era opened, the antiquity of man was shown to be much greater than the few thousand years which the Biblical chronology allowed it. And but little later, Darwin, after holding his growing ideas under "study and meditation for nearly twenty years," announced his revolutionary, evolutionary theory, including man's development from some anthropoid mammal, and thus presented a new philosophy to an unwilling, a very unwilling world.

It must not be imagined that the makers of these great discoveries had been working with the object of unsettling religious opinions; not in the least. They were devout men, possessed of vigorous intellectual curiosity, who were objectively pursuing geological and biological studies simply with the wish to learn the truth, whatever the truth might be. They rarely if ever precipitated a conflict by attacking the theological beliefs which their discoveries traversed. The attack was made by the theologians, most of whom were wholly untrained in scientific habits of thought. When the above discoveries, particularly Darwin's, were announced, the violence of the protests they aroused among the orthodox can hardly be credited to-day. Men learned in Christian theology then asserted, "Darwin requires us to disbelieve the authoritative word of the Creator"; and again, "If the Darwinian theory is true, Genesis is a lie, the whole framework of the Book of Life falls to pieces, and the revelation of God to man, as we know it, is a delusion and a snare." Not twenty years ago, a preacher told his congregation that God had made monkeys look like men so that heretics should be led into error! In a word, the clergy of the Victorian era, as well as some of their successors, were still as much blinded to the grandeur of the evolutionary scheme of the varying organic world as their predecessors had been to the grandeur of the Copernican scheme of the solar system. It is therefore gratifying to know that, some twenty-five years after Darwin's "Origin of Species" appeared, a broader view of the world was taken by Bishop Temple of London who wrote: "It seems something more majestic, more befitting Him to whom a thousand years are as one day, thus to impress His will once for all on His creation, and to provide for all the countless varieties [of organic forms] by this one impress, than by special acts of creation to be perpetually modifying what he had previously made."

A curious feature of the objection to Darwinism was that, while it strained at the little gnat of specific evolution, it unhesitatingly swallowed the huge camel of individual development. Of these two processes the latter is immensely the more marvelous. It involves for every individual the change from a slightly differentiated ovum into an elaborately differentiated adult, closely resembling its parents; and during this change there is, first, a rapid recapitulation of many ancestral antiquities, and later a more gradual addition of certain evolutionary novelties. On the other hand, the appearance of a new species involves only the addition of a few extra-novelties, highly significant for the species then appearing, but nothing like so wonderful

as the long sequence of inherited antiquities which precedes them. But the huge camel of individual development was, like the magnificent phenomena of sunrise and sunset, a familiar commonplace which the Mosaic record took as a matter of course, while the little Darwinian gnat of specific evolution was a choking innovation, which the Mosaic record explained by supernatural acts. And these supernatural acts were believed in by the multitude, because the unscientific mind desires a supernatural power to enter frequently into mundane affairs, where the scientific mind sees only the orderly working of nature.

The story is told of an African chieftain who, thirty years ago, watched the construction of the steel-arched railway bridge across the gorge of the Zambezi. At its beginning he told the engineers: "You can never build it across." When it was built across he said: "It can not bear the weight of a train." Finally, when a train was safely driven over it, he said: "The finger of God holds it up." But the engineers said: "The bridge stands and bear the weight of the train because of the strength of its steel." This story has a long moral. Many devout Victorians, sixty or seventy years ago, could not believe that anything so marvelously intricate as the development of successive organic forms could be accounted for by natural processes. Like the African chieftain they could not leave out the "finger of God." But Darwin said: "I believe in the doctrine of descent with modification, notwithstanding that this and that particular change of structure can not be accounted for, because this doctrine groups together and explains . . . many general phenomena of nature." And the grandchildren of the devout Victorians now, with no loss of devoutness, follow the belief of Darwin rather than that of their grandparents. Such is the order of human progress.

But why repeat these old stories of the Victorian era? There may perhaps be present some persons who are so completely modernized that they look upon that era as already too much talked about, because it was so fatiguingly prim and platitudinous. Truly, its earlier years were rather prim, for church-going two or three times every Sunday was then a matter of course for the piously respectable part of our population: but it is that very primness which must be understood if we, much less prim, are to measure our indebtedness to science for having led us out to a more vigorous life.

It must be remembered that hell and the devil were vivid realities to devout Christians in those recent days; and that some very orthodox parents then taught their children an awful catechism. The loving parent would ask: "Doth original sin wholly defile you, and is it sufficient to send you to hell, though you had no other sin?" and the little child was to answer, "Yes," though no child could possibly have any adequate conception of that shocking doctrine. Again, when asked: "What is your natural state?" the little one was to say: "I am an enemy of God, a child of Satan and an heir to hell." Could anything be more incredible? Yes, more incredible still, parents were informed by the authorities of their church that it was proper, even before the little ones had learned to read, to teach them those frightful answers and others equally far beyond childish understanding. There are actually men now living who were taught that sort of thing in their early years by their fathers. Do any of those men, I wonder, now teach the same catechism to their sons? Very few of them do; and it is to scientific rationalism that they owe their deliverance from such folly. If the question is again asked, Why repeat this old story of the Victorian era? the further answer may be given: It is

repeated in order to show the younger generation of to-day, who are now growing up in ignorance of such stories, how recent is the escape of many of us from the theology of medievalism, based on ancient myths.

It is truly difficult to believe that such theological beliefs were persisted in by devoted, conscientious men, who therefore violently opposed anything so heretical as Darwinism. On the other hand, there were also many liberalized rationalists who welcomed the new discoveries and rejoiced in the better understanding of the world that they provided. But there was an intermediate and very important class of Victorians; for between the unyielding conservatives and the open-minded rationalists was a large number of somewhat mobile-minded yet still orthodox believers, who could not altogether reject the new discoveries, although they had a hard time accepting them. Many of those earnest men suffered great mental distress on finding that certain elements of the creed which they had been taught as essential verities were so inconsistent with the findings of science that they must be regarded as erroneous. And the more logical of them perceived, with still further distress, that if the Bible, which they had been taught was infallible from cover to cover, were shown to be fallible in one or more of its parts, the infallibility of the rest was thereby made questionable, to say the least. To what guide should they turn if the guide that they had so devotedly trusted proved to be not wholly trustworthy? Moreover, if they gave up the infallibility of the Bible, would they not thereby forfeit the right to call themselves Christians? That fear caused profound unhappiness to many sincere men before they found their new bearings. But some of them at least were wisely shown that if they followed the example of their orthodox predecessors in studying and interpreting Christ's teachings under the best advice they could get, and if they then still experienced a joyful exaltation over the profound ethical value of the teachings and a warm desire to live in accordance with them, they would have just as good a right to count themselves among his followers as any one else. In that happy conviction, thousands and thousands of former conservatives, liberalized by the discoveries of science, are living to-day.

It is as if the mobile-minded orthodox believers of recent time had been near the top of a long flight of stairs, each step of which represented an article of faith, and on or near the top step of which their great-grandfathers had stood. Wherever the mobile-minded orthodox found themselves, they at first insisted they would never take a single step downward. Then in a few years, finding themselves, in consequence of more or less unconscious thinking, several steps lower on the long flight, they again insisted they would never descend any more. But they did, step after step; and many of them are now not far above the solid ground of rationalism at the bottom of the flight. If they should turn and look back at the long flight, they would marvel at the insecurity of the scaffolding that holds it up! And if they there conferred with one another, they would say: "How few of us to-day hold all the beliefs that our fathers so ardently held!"

Scientific Study of Religions. One of the most potent causes of disconcertment to orthodox theologians, not yet mentioned, was actively at work all through the last century; namely, the application of the objective, scientific method, not alone to the study of plants and animals, not alone to the study of the structure and history of the earth and of the distance and composition of the stars, but to the study of religions. In spite of their wide diversities the religions of the

world were thus found to show a broad community of content and an inherently human origin. They very generally make more or less definite claim of intercourse between their founders and their gods, or of revelations *to* their founders *from* their gods, or of miracles which attest the power of their gods or the authority of their founders. Some religions are found to be more, some less refined in their ethics; but whatever form they take, they reflect much of their natural environment. Among the factors of environment must be included the characteristics of the people who develop them, as well as the climate and the topography of the region in which the people live. In an open country where occasional mountains rise over lowlands, mountain tops have repeatedly been chosen as residences for the gods, or as sites for altars where sacrifices to the gods should be most fittingly made. It is on the seacoast that a god of the sea is worshipped; it is in the desert that a god of rain is worshipped. That is, the gods vary with the homes and the needs of the people who pray to them; they vary also with the ethical standards of their worshippers.

But whatever the quality that a religion acquires, its believers, knowing little of any religion but their own, naturally take it to be superior to all others; its gods are the greatest gods; its people are divinely favored. This self-centered belief has made many an ardent young Christian missionary much harder-hearted and harder-minded than he should have been with respect to the beliefs of the heathen whom he was sent out to convert to what he earnestly believed was the only true faith. In contrast to that self-centered belief, the more sympathetic belief of the student of religions is such that he comes to see in every religion the striving of humanity toward a fuller understanding of man's place, man's opportunity and man's duty in the world. And this surely makes for brotherhood and good will among men. The change that has thus been made desirable in missionary work is most beautifully and understandingly set forth in a remarkable report[3] made last year by an interdenominational "Commission of Appraisal" of fifteen members, who visited India, Burma, China and Japan. Further reference will be made to it later.

Great benefit has been conferred upon Christianity from scientific study of another kind, closely related to the scientific study of religions; namely, from the scientific study of the Bible, the so-called higher criticism. This study has applied a most helpful correction to the beliefs of irrationally convinced credulity by the use of impartial rationalism. One may now, guided by the illuminating results of such study, appreciate the great value of the Bible as a venerable human work; manifestly human in its naïve record of various scandalous stories about its leaders as well as in the candid record of successive stages in a great advance from savagery to barbarism. Moreover, as long as the Bible was regarded as the infallible "Word of God," there were persons who, with more sense than sympathy, scoffed at it because so many of its passages are ungodly. But the ground is taken from under the feet of scoffers when the human origin of the Bible is recognized; for then its cruder passages are seen to be only the inevitable imperfections of struggling humanity, with which we, still struggling *to-day,* must warmly sympathize.

If some passages in the Old Testament are fatiguing in their enumeration of the generations of Adam or of the places where the Israelites "pitched" during their traverse of the Wilderness, many

3 "Re-thinking Missions," by the Commission of Appraisal, W. E. Hocking, *chairman.* New York, 1932.

of its passages are inspiring. How grand is the solemnity of the first four words: "In the beginning God." Even a rationalist must respect the devoutness of the nineteenth Psalm: "The heavens declare the glory of God; and the firmament showeth his handiwork." Where can be found a finer gem of reverent thought, even though it lies amid much dross, than Micah's declaration: "For what does the Lord require of thee but to do justly, and to love mercy, and to walk humbly with thy God." And if some passages in the New Testament, especially in Revelations, are extravagant, who can fail to marvel at the words of Jesus, uttered in an age of violence: "Love ye your enemies, and do good . . . and ye shall be children of the Highest; for He is kind to the unthankful and the evil. . . . Be ye therefore merciful as your Father is also merciful." His reputed miracles in the way of casting out devils are as nothing compared to his clear perception of the value of gentle goodness.

The Recent Period of Reconciliation. The transition from the Victorian era to the present time is of particular interest to those of us who have lived through it, not only because it has witnessed an unprecedented advance of science, but even more because it has been characterized by an amazing reconciliation of Christian theology with science. To be sure, there are still many earnest preachers who, like the conservative hold-fasts and die-hards of 80 years or more ago, can not give up the beliefs of their fathers. Instead of being the leaders of their congregations into the newer understanding of the world, they are vainly striving to hold them back in the older misunderstanding. This is because they were treated when young very much as the children of the Flathead Indians are—or used to be—treated. Stiff boards were bound to the Indian children's heads, so as to flatten their skulls as their parents thought they ought to be flattened. Similarly, the children of the ultra-orthodox Christians have had stiff theological creeds and catechisms bound to their minds, so as to shape them as their elders devoutly thought they ought to be shaped. It is therefore most natural that, when such children grow up, their minds remain so shaped; they can not reshape them if they would, especially not if they become ministers pledged to maintain the stiff beliefs to which their minds were bound in their growing years.

It was a mind-bound conservative of this kind who not long ago exclaimed: "If I could not believe that Joshua made the sun stand still in the heavens, I should lose faith in the Bible and in God." He had probably been educated in one of those sectarian colleges, to which orthodox parents send their sons to safeguard them from scientific error. It was as a teacher in such a college that a young Harvard graduate was some years ago, as he later told me himself, instructed on his arrival there by the president of the institution: "You may teach as you like about minerals and rocks, but if the students ask you about the age of the earth, refer them to me."

Theologians would have found their change of belief easier had they been scientifically educated, but they have not been. They have presumably studied "apologetics," in which they learned how to argue out a problem; but that method of argumentation is not free; it is directed to the support of a predetermined conclusion and is therefore absolutely unscientific. The essence of scientific method is that it gives equally impartial consideration to all conceivable solutions of a problem, and adopts the one which pragmatically works best, after it has been tested by many men in many places through many years. But it is recognized also that the human mind is not infallible, and therefore all

adopted solutions are open to revision whenever new evidence bearing upon them is discovered. It should be understood, however, that scientific method thus characterized is a modern development, the result of centuries of experience; for although the science of logic is of more ancient origin, its unprejudiced application to scientific problems is difficult to learn, even in scientific schools; and it is probably never learned in theological schools.

In spite of all obstructions, liberation from outworn theological creeds seems to have been repeatedly accomplished during the period of reconciliation, even among conservatives, by a gradual and insensible shift of belief. The shift has rarely been caused by direct argument, and it has nothing whatever in common with the hysterical conversion to religion of old-fashioned camp-meetings. The shift is in great part a consequence of the simple process of growing up in the rationalized atmosphere of modern times. The present generation has become habituated to accepting the results of scientific discoveries. It has at the same time become increasingly incredulous about miracles, which are now more and more overlooked, neglected, forgotten. Along with the rationalizing influence of scientific progress has been a marked lessening of the antagonism which used to prevail between religious sects; and a falling-off in the number of severely doctrinal sermons, the kind that used to expound "hell-fire religion."

There has also been a marked relaxation regarding matters of belief. One of the most striking instances of this kind was that by which the implied damnation of non-elect infants was omitted from the confession of faith of one of our most important denominations. Many of the laity and clergy had practically ceased to believe it, and finally at a General Assembly of the church in Philadelphia about thirty years ago, the phrase "Elect infants dying in infancy are saved" came up for discussion. A motion was made to strike out the word "elect," and the Conservatives objected that there was no specific Scriptural evidence that all infants were saved. In the vote which followed, however, they were decisively beaten and it was then officially declared in the faith of that denomination that "Infants dying in infancy are saved." When the motion was declared carried, an elder arose—he must have had a keen sense of the humor of the situation, in which a majority vote of ministers and elders could be taken as deciding how their God would act—he arose and said: "I move that vote be made retroactive." The solemn assembly was overcome with laughter. Let it be noted that that antiquated doctrine was not argued away; it was simply sloughed off by the weight of its inherent absurdity and soon forgotten. Should we not be very grateful to the growth of scientific rationalism by which so monstrous a belief was crowded out of acceptance?

The rapid advance of rationalism during these recent years may be seen by comparing the beliefs held at successive ten-year periods in the life of a single individual. It has been written by an experienced evangelical clergyman that "the recognition of the orderly working of nature weakened confidence in the miraculous, and as years passed theologians . . . interpreted scenes, teachings and epistles of the Bible in a way that would have shocked themselves ten years before." We may tell further of a man of altogether admirable character who had been taught as a boy the standard Christian myths, such as that of the devilish serpent which talked with Eve in the Garden of Eden; and who, after giving up those childish beliefs in his early manhood, found that still further liberalization was experienced in his mature years. He thus in a single life-

time came down many steps from near the top of the long flight where his excellent father had stood, but he is not yet at the bottom. However, if he lives a few decades longer he may, after interpreting the Bible's teachings in a way that would shock himself to-day, come farther down, nearer the solid ground of wholly rational belief at the bottom of the flight. Many examples of this rationalizing process may be found among one's friends, if not in one's own experience.

There is one disappointing element in this story. It has often been claimed that the marvelous progress of civilization in Europe has resulted from the adoption of the Christian religion; and it would be indeed gratifying to know that the refined ethics of Christianity have really brought about that progress. But in view of the dependence of European civilization largely on the advance of science, which did not begin until the revival of learning, centuries after the adoption of Christianity, and in further view of the persistent opposition with which the organized forces of Christianity so generally resisted the advance of science even in so beneficent a study as medicine, and in still further view of the dominance even to-day of many non-Christian principles of behavior among peoples of European stock, the claim that European civilization is a result of Christianity can be allowed only in part, perhaps only in small part. Modern European civilization is the result of mental rather than of moral achievements, and as such it is more closely associated with the mentality of European peoples than with the religion which they adopted nearly 2,000 years ago, the ethics of which they have not yet learned to practise. Had they done so, the claim would be more true. It may, indeed, be seriously doubted whether Christian ethics had much to do with the adoption of organized Christianity by early Europeans. They were an ignorant, superstitious, credulous, warlike and cruel people, and it may be well believed that they made professions of Christianity less in order to practise, during their lives on earth, the lofty ethical principles preached by its Founder, than to secure for themselves through a vicarious atonement for their natural sinfulness a blissful future life in heaven promised by propagandizing theologians, and thus to escape a threatened eternity of torture in a horrible hell.

Human Origin of All Religions. It was said at the beginning of this address that all religions, like all sciences, should be regarded as the natural products of the human mind. It was added that the grounds for that belief would be stated in this part of the address. The grounds are these. First, as to Christianity: Many theological elements of our religion, based on Scriptural texts, have been shown by scientific research to be erroneous; they can therefore be no longer taken as infallible revelations; they are only humanly invented beliefs, accepted by the ancient Asiatic people who recorded them. But various other elements of our religion are still held by conservatives to be of supernatural origin. They are so held on the evidence of other Scriptural texts; and these other texts, being of essentially the same nature as those formerly held to demonstrate the supernatural origin of the abandoned beliefs, can no longer be taken as competent witnesses to the truth of the remaining supernatural beliefs. Hence these remaining beliefs should also be interpreted as humanly invented. The upshot of this is that, while the Bible unquestionably gives us an invaluable record of the beliefs of an ancient people, the competence of its texts as witnesses for the supernatural is invalidated. The same argument applies to all other religions, but with less

directness because they have not come into conflict with science so much as Christianity has.

A corollary of this conclusion is that the precepts of our religion should be accepted not on authority but on merit. They should be judged, just as we judge the precepts of other religions, by their appeal to our moral sense. In support of this conclusion let us recall the various traditional beliefs which, passed down to us from an ignorant and credulous people, were for centuries held to be essential elements of the theological part of our religion: recall the proposed replacement of those beliefs by the findings of science, won from nature by patient, truth-loving research; recall the vehement protests conscientiously made against such replacements because they contradicted the "Word of God"; recall finally the gradual fading away of the protests and the acceptance of the protested replacements. What a striking resemblance there is in all these stories; the same sequence over and over again. Should we not learn from so uniform a repetition of the same experience that the Bible is, as just said, not a competent witness to the occurrence of supernatural events in human history, and that it should be studied as other human records are studied?

But let another matter be recalled. All the discarded elements of Christianity thus far noted are of a theological, not of an ethical nature. The ethical elements of Christianity have not been disturbed; they have not been discarded, even by those who believe in the humanity of their great preacher. Nor has the value of the ethical elements been lessened in the least by the abandonment of the theological elements. The great principle, "Whatsoever ye would that men should do unto you, even so do ye also unto them," is still as valid as ever. Indeed, its validity has been strengthened by the comparative study of the races and the religions of mankind. In a word, the whole drift of scientific opinion through the centuries since the revival of learning has been away from theological superstition toward rationalism; and during the same centuries, Christian ethics have been gaining ground. This is true, notwithstanding the fact that the principles of Christian ethics are, like those of the ruder ethics which they have displaced, increasingly regarded as of purely human origin, quite as much so as tables of logarithms or of chemical elements.

It is, of course, to be expected that many persons will dissent from the untraditional views just expressed and will continue to believe that, however human other religions may be, our own Christian religion is truly based on supernatural revelations; and they will thus resemble the African chieftain who believed that the finger of God gave an otherwise incredible strength to the Zambezi bridge. To them should be told the story of George Fox, founder of Quakerism, and his convert, William Penn. George, meeting William not long after his conversion, said: "William, I see thou art still wearing thy sword." "Yes," said William, "it seems best to wear it." "Wear it as long as thou canst," replied George; and the next time they met, William wore no sword. The moral of this story is that those who still devoutly believe in the occasional interruption of natural processes by supernatural processes should continue to hold that belief as long as it is helpful to them. Only when it ceases to be helpful should it be set aside. But that such beliefs have repeatedly ceased to be helpful is shown by the vast number of modern William Penns who have rationally given up wearing their theological swords in the last seventy or fifty or thirty years.

The change of mental habit thus indicated has been astonishingly rapid; more

rapid, indeed, than corresponding changes have been made in the creeds of rationalized church members. Indeed, many churchmen have been led by orthodox preaching to think that theological beliefs constitute so essential a part of Christianity that, when they found those beliefs no longer tenable, they thought they no longer had any religion. This is greatly to be regretted, for the majority of those men really still hold the essentials of Christian ethics in their hearts as their ideal.

Before turning to my next topic, let me point out one feature of the growing reconciliation of Christian theology with science that is of especial significance. The reconciliation is not a compromise, in which each side has yielded something. It has been brought about wholly by the modification of theological views so as to bring them into accord with scientific views. Not a single one of the various scientific discoveries which, at the time of their announcement, proved to be so disconcerting to the orthodox, has been reversed. On the contrary, the estimates of the earth's age and of the antiquity of man are now greater than when they were first calculated; and the evidence in favor of organic evolution is immensely stronger than it was in Darwin's time. True, there was a flurry some twenty years ago, when an eminent English biologist, Bateson, declared in an address at Toronto that "Darwinism is dead," or words to that effect. The half-informed public misunderstood him to mean that evolution is dead. He meant nothing of the sort, for he was a pronounced evolutionist! What he meant was that the process of natural selection, which Darwin had thought was the mainspring of evolution, was in his opinion inadequate, and that evolution had been brought about in some other way.

PART II

Clearing the Ground. Before taking up the "Faith of Reverent Science," to which the foregoing pages may serve as a preface, let a word of warning be introduced. Thus far much has been said of various outworn theological beliefs which have been displaced by rational beliefs. Perhaps that has given the impression that the object of my address is destructive. Not so! The object of the address is constructive, in that it places great value on the sounder beliefs which have replaced the outworn beliefs. The case is like that of our pioneer forefathers, who had to clear away the forests before they could plant their productive crops. Similarly, science has had to clear away old errors before it could implant new truths; but that is a wholesome, constructive process. It is, however, because of the abandonment of the outworn beliefs by scientific rationalists that the orthodox have so often given them the derogatory name of unbelievers, although the rationalists felt themselves to be just as ardent believers of the faith that they maintained as the orthodox were of theirs.

What, then, are the beliefs of scientific rationalists? No one can say definitely what they are, because rationalists have not organized themselves into a religious body and therefore have not as a body formulated a creed. No one is authorized to speak for them; they are individualists; like St. Paul, each one holds his own gospel (II Tim. 2: 8). This is, in one respect, unfortunate, because, standing alone, they lose the great advantage of concerted action; but, on the other hand, they conserve a freedom of thought, which organization is likely to limit. They might, however, unite in neighborhood churches, where each member would be "free to follow truth as he sees it to its uttermost bounds," yet at the same time "enjoy religious fellowship with others and work together for the common good."

But besides being unorganized there are, among scientific rationalists, as among other groups of our population,

persons of unlike temperament: some of them take religious matters lightly, inattentively; others of them take such matters seriously and reverently. It is with the latter sub-group, whose faith may therefore be called the faith of reverent science, that we are here concerned. It is highly significant that, as far as I can judge from a considerable acquaintance among them, they hold many of the essential principles of Christian ethics. Those principles are, as already told, fortified by scientific research, not only because they harmonize with the great modern truths which have supplanted Biblical myths, but also because so many of them are represented in other great religions, also of human origin like ours.

The Faith of Reverent Science. The chief articles of the faith of reverent science, thus understood, may be summarized as follows.

(1) Reverent science devoutly refrains from assuming to know the nature, the thoughts, the acts of a Supreme Being by imputing even the best of human acts and thoughts and nature to him. It stands humbly silent before the ever-expanding mystery of the universe. In the sincere agnosticism of profound ignorance regarding the supernatural, no satisfaction is found in the limitations of a Supreme Being which invariably accompany the attempt to define him. Let no one make the blunder of confusing this agnostic attitude with atheism: inability to form an estimate of a quantity is no ground for saying its measure is zero. Recognition of our ignorance regarding supernatural matters goes with the growth of our knowledge regarding natural matters. It was appropriate enough in Noah's time, when little was known of the world, that a legend should describe a creator who repented of his creation. Somewhat later, Moses still knew so little of the world around him that he did not hesitate to define his chief deity in very human terms, even to the point of conceiving him as being shamed out of his wrathful threats by human reproaches. From then till now a long series of concepts has been promulgated, generally becoming more refined as time went on, although one of the most popular included a malevolent Devil working in conflict with a beneficent God. The humanly inconceivable quality of immanence came to be attributed to Deity by metaphysical theologians, but that quality must be terribly strained, even to metaphysicians, now that the universe is found to extend, along only a part of one of its dimensions, for 300,000,000 light-years. It is on reviewing these various unsatisfactory hypotheses that the reverent scientist retreats to humble silence.

But by no means are all scientists silent agnostics in this matter. One of our leading physicists is reported to have said: "It is through science that man has discovered that his own soul is God's greatest purpose in the universe": but it is not explained how the discovery was made. Another defines the "God of science" as the "spirit of rational order"; but without going on to specify the place that is occupied in rational order by the terrible griefs caused to humanity by irresistible hurricanes, devastating floods, incurable plagues and above all by barbarously irrational wars.

Agnostics are baffled by the cruelties and miseries of the world; always a marvelous and often a beautiful world, but also for ages and ages a merciless world, on which, even while the gentle rain fell from heaven, carnivora remorselessly devoured herbivora; and even now sometimes a terrifying world, as when an unforeseen earthquake wave sweeps away a whole village of simple fisherfolk; and too often a cruel world, in which, until a few years ago when

medical science came to their relief, countless innocent and devoted young mothers have had, through no fault of their own, to endure the agony of seeing their little ones, whom they had no power to cure, strangled to death before their eyes by diphtheria. The mystery of such a world is too profound for our solution. The easy invention of a devil gives no acceptable aid in understanding it. Hence in no spirit of irreverence but only in the sincere humility of acknowledged ignorance does the agnostic refrain from making assertions regarding a Creator.

(2) Reverent science has a secure faith in the persistence of the order of nature through time and space, because such persistence has repeatedly been shown to be in the highest degree probable; but it is not absolutely proved; science has no means of reaching absolute proof in matters of such magnitude. Yet in view of this faith, certain reported events, known as miracles, which interrupt the order of nature, are discredited because there is no sufficient evidence forthcoming that they have ever taken place. Such disbelief is confirmed by the historical fact that alleged miracles are usually reported from ignorant and uncritical communities. With the vanishing of belief in miracles, legions of elves, gnomes, imps, witches, demons, devils, fairies, spirits and angels have also vanished from among us.

It is not alone among rationalists that miracles are disbelieved to-day. Many of our orthodox churches now discredit certain Biblical miracles which, a generation ago, were literally believed. Consider, for example, the miracle performed by Christ in calling forth devils from a demoniac, and at their entreaty giving them leave to enter a herd of swine. Is there to-day any one who believes that the demoniac was possessed by actual devils; or that when they came forth from him they orally besought Christ to let them go into the swine; or that, on being given leave, they actually entered the swine? Does not every one now take the central episode of the story to be an example of more or less hypnotic healing, and then interpret its miraculous elements as legendary attachments demanded by the ancient belief that certain diseases were due to possession by devils; the swine being introduced as the best means of disposing of the devils when they came forth from the demoniac.[4] And when thus interpreted where is the miracle?

The orderly wonders of science would have been taken for miracles by peoples of ancient and medieval times, as they still are by modern savages. Some of them may well seem miraculous, even to intelligent moderns. Consider, for example, the computation of a comet's orbit, as worked out by Gauss on the basis of Newton's laws. A new comet is ordinarily, when first seen, only a small and faint nebulous wisp, with neither head nor tail. Its distance from us and its direction and velocity of motion are unknown; yet if three observations of its apparent position among the stars are made at intervals of about a week, as it is seen from our revolving, rotating earth, it is then possible to calculate not only its distance from us and the direction and velocity of its motion at the times of those observations, but also where it will be seen among the stars and how it will be moving at any desired date for a considerable period of time in the future. This suffices to show how enormous is the range of human mentality, a conclusion that should not be forgotten when we are tempted to regard the announcement of new ethical principles as necessarily indicative of superhuman powers.

(3) Reverent science believes that various communities or tribes or peoples

[4] The long-continued opposition of theologians to medical science is broadly treated in White's "Warfare. . . ." II, Ch. xii.

have, through their purely human efforts, gradually formulated not only their theological beliefs but also such rules of behavior, or codes of morals, or principles of ethics as seemed fitted for their needs in the successive stages of savagery, barbarism, civilization and enlightenment. It is therefore concluded that, like all other codes, the Christian code has been humanly formulated instead of supernaturally revealed. A strong support for this conclusion is that many of the so-called revelations of the Bible do not seem beyond man's own discovery; also, that the essential equivalents of many Biblical revelations are found in other religions.

Moreover, the human origin of the Biblical systems of ethics, as well as of other systems, is strongly indicated by their gradual improvement with the passage of time and with the progress of the peoples who formulated them. Let us not forget in this connection that, if we go back far enough, lying, stealing and slaying have not always been "wrong." Such acts were instinctively "right" among our semi-brutal ancestors, and they did not become wrong until, after thousands and thousands of years of experience, they were first condemned by moral leaders, and later condemned by the local public. Similarly, some acts which we consider right may be in time condemned by our improved descendants. It is truly difficult to believe that "right," as we know it, is not a matter of objective reality but only of subjective human opinion, subject to change as humanity advances. Many persons may refuse to believe that acts which we hold to be wrong were ever right; yet such acts had, in their time, just the same claim to be right as our gentler and more merciful acts have today; namely, the general approval of their communities as guided by their leaders: for example, Moses, the great law-giver, boasted of how he had taken all the cities of Sihon, "and utterly destroyed the men, and the women, and the little ones, of every city"; and of how he had likewise taken all the cities of Og, king of Bashan, "utterly destroying the men, women, and children of every city" (Deut. 2: 34; 3: 6). Centuries later, the gentle little Samuel thought, after he had outgrown his childish gentleness, that it was his Lord's wish—and therefore surely "right"—that Saul should smite the Amalekites and "slay both man and woman, infant and suckling." And therefore Saul "utterly destroyed all the people with the edge of the sword," sparing only Agag, the king; but Samuel made up for that sinful omission, for he himself "hewed Agag to pieces before the Lord" (Sam. I, 14).

It is truly a difficult proposition to believe that what we think is "wrong" could ever have been "right." Many persons may shrink from accepting it; but what other conclusion can we reach if we face the facts; that is, if we study open-mindedly the evolution of savage man from brutes and of civilized man from savage man. Thus explained, an evil act of to-day, whether it be a sin against a religious code or a crime against a civil code, is generally nothing more than an act that was permitted and condoned in an earlier era, but that has come to be condemned and prohibited in a later era. The torture of prisoners of war was once a matter of course; now it is as a rule no longer sanctioned. Human nature has changed for the better.

(4) Reverent science preserves an earnest faith in the value of sacrificing one's own selfish preferences for the common good and of prayerfully consecrating one's best efforts to the betterment of humanity; but it has very generally given up the belief in the possi-

bility of turning the course of events, which are beyond one's own control, into a desired direction either by the sacrifice of animals or by the prayer of humans. A waning belief in the efficacy of prayer is one of the most marked effects of the waxing influence of rationalism. It goes with a fuller realization of the persistence of the order of nature. More than any other phase of rationalism it varies with personal temperament. Many persons no longer pray for rain during a drought, because they have come to understand that rainfall results from natural movements of the atmosphere; but the same persons may pray for the recovery of a friend from illness, perhaps because of a feeling that human affairs are less physical, more spiritual than atmospheric movements. Yet science has shown that human illnesses involve conditions and processes that are quite as natural as those which control rainfall, even though organic instead of inorganic. But what shall be said of a hospital which announces on advertising cards in London buses that it is supported wholly by prayer? If it be so supported, why should such an announcement be posted?

(5) Reverent science accepts, without asking that it shall be revealed to us, whatever fate is in store after death, be it immortality or annihilation, in the complete trust that it is a fate fitting the part we have to play in the unfathomable mystery of existence. It leaves aside all transcendental questions about the imagined regions of heaven and hell, and it rejects absolutely the monstrous doctrine that most of mankind have long been and still are condemned to horrible torment after death; also the specious doctrine that salvation from such a fate has been and is still granted to but a small minority of mankind, and to them only through vicarious atonement for sin they never committed, the original sin of a fictitious Adam. The jealous Jehovah visited, according to Moses, "the sins of the fathers upon the children unto the third and fourth generations," but Christ's merciful Father in Heaven has been made by some would-be Christians unforgiving to the children of countless generations of those that never had opportunity of hearing of him. The persistence of this doctrine of damnation into our times must do serious injury to Christianity in the minds of intelligent "heathens."

Let me draw special attention to the first two lines of this article: "Reverent science accepts, without asking that it shall be revealed unto us, whatever fate is in store after death." This acceptance of ignorance of the unknown is characteristic of an honest scientific attitude with regard to an unsolved problem. A suspended judgment is maintained, which refuses to settle down on an unwarranted solution. That attitude is distasteful to the scientifically untrained; they do not wish to suspend judgment; they wish to adopt some preferred solution instead of remaining agnostic in the absence of a demonstrable solution. It sometimes seems as if not only persons of untrained minds, but also certain highly trained philosophers and metaphysicians were likewise unwilling to suspend their judgment; for, after discussing problems that are far beyond solution by scientific methods, they appear to settle down on one or another solution of such problems, their choice being guided more by subjective preference than by objective proof.

(6) Reverent science is much concerned with making our life on earth as good, as unselfish and as helpful to others as possible, not in order to receive posthumous reward for doing so, nor in fear of posthumous punishment for not doing so, but in the convinced belief, based on long human experience,

that in a life so conducted—a simple, kindly, helpful life—man finds his highest and deepest satisfactions and his fewest regrets; a convinced belief that doing good in a sincere and unselfish spirit is man's best means of maintaining the progress of the past and of contributing to the progress of the future; a convinced belief that in so conducting his life he is playing the best part accessible to him; and that while so conducting it he will find his truest happiness in his home, with his neighbors, among his countrymen and over the whole world.

Summary. The foregoing articles of faith suffice to show that no one who holds them should be called an unbeliever; for they represent the essence of Christianity, after many mythical, miraculous and theological elements have been withdrawn from it. Alas, that it is so much easier to state these articles than to practise them! Alas and alas, that even while earnestly believing them one may fail and fail again to live up to them. Without making that confession I should not be willing to write these pages.

One of the large merits of such a faith as that above outlined is that it may easily keep pace with the growing knowledge of the world. No one who holds it would be content to use, as his guide, a creed formulated centuries ago by majority votes of credulous and disputatious theologians and based on texts several centuries older, or a body of documents of doubtful authenticity older still by many more centuries. Yet certain well-organized religious denominations still profess to be guided by such creeds and texts and documents. In such profession we find an unfortunate consequence of the very rapid reconciliation of theology and science, because the change of religious thought involved in the reconciliation has taken place so fast that the change of formal expressions of religious belief has not kept pace with it. The laity of such denominations, therefore, find themselves in the dilemma of either sitting under hold-fast conservatives who are as out of date as the creed they have solemnly promised to preach, or under liberalized progressives who have as solemnly promised to preach a creed which they no longer believe; and the worst of it is that the laity are so indifferent to their dilemma that they take no efficient steps to get out of it.

It may, perhaps, be thought that what has been said thus far about the reconciliation of Christian theology and science goes too far. Remember, therefore, that the reconciliation has not been described as by any means complete, but only as rapidly growing and as being in some quarters already far advanced. In support of this conclusion, let me here read some extracts from the above-cited report, "Re-thinking Missions," by a many-denominational Committee of Appraisal. They unanimously agree on the following statement: "Only a religion whose first principles are capable of the simplest formulation can become a religion for the modern man. . . . The religion which assumes too much knowledge of the supernatural realm, its system of heavens and hells, or its inner mechanisms of eternal justice, can no longer be a living issue."

Or again: "Western Christianity has in the main shifted its stress from the negative to the affirmative side of its message; it is less a religion of fear and more a religion of beneficence. It has passed through and beyond the stage of bitter conflict with the scientific consciousness of the race over details of the mode of creation, the age of the earth, the descent of man, miracle and law, to the stage of maturity in which a free religion and a free science become inseparable and complementary elements

in a complete world view. Whatever its present conception of the future life, there is little disposition to believe that sincere and aspiring seekers after God in other religions are to be damned; it has become less concerned in any land to save men from eternal punishment than from the danger of losing the supreme good."

The following passage concerning the larger Christian denominations is also instructive: "They were formed at a time when a precise and definite theological system of doctrine was generally stressed as vitally important, and this theological emphasis has remained up to the present time a dominant feature of these conservative churches. This excessive occupation with theological doctrine has kept such churches out of touch with trends of thought and intellectual problems in the world around them. Churches of this sort appeal only to a certain type of mind. Students in the main leave them coldly alone and are apt to be turned against Christianity if this is the only kind of Christianity which they know. It seems to them too often a complicated religion of words and phrases, dealing with the issues of a former age, not a living force for the moral transformation of the world and for the remaking of the present social order."

Strong support is thus given to the above-stated faith of reverent science, but its various omissions may make it unsatisfying to many devout Christians who, although now standing much lower down on the long flight of theological steps than their grandfathers did, have not yet descended to the foot of the flight. They surely have the same right to adopt and maintain their beliefs as we have to form and maintain ours. As long as their beliefs help them to lead good and happy lives, let them be held fast; for in addition to the above-recited articles of the faith of reverent science, there is another: "Give up no belief until it may be replaced by a more helpful one." Thus may be avoided the unhappy fate of those who, over-rigidly brought up, think that the abandonment of their early faith leaves them with none.

Reflections. Let us now turn to some reflections on the statement made at the beginning of the address, that all religions are, like all sciences, of human origin; in other words, that religion and science are both examples of the natural evolution of human thought. Note particularly that this does not involve any change in the articles of belief of any religion. They stand unchanged. True, the attribution of religious beliefs to human sources may cause a change in the attitude of those believers who are accustomed to taking authority for truth; they may feel differently toward the religion they profess if they come to regard it of human origin. But others who are trained to take truth for authority will not change their attitude; the evidence which had previously convinced them of their religion's verity will still convince them. Dissent from the view that all religions are of human origin will of course be expressed by the conservatives of to-day, just as their grandfathers two generations ago expressed dissent from the view that all plants and animals are examples of the natural evolution of organic forms. The present-day conservatives will urge that at least their own religion is based on supernatural revelation; and the same claim would be made by the conservatives of other races, if the question ever arose among them. The present conservative belief in the supernatural revelation of various religions is therefore a parallel to the orthodox belief of our grandfathers in the supernatural creation of organic species. But this latter belief has

been given up by many intelligent persons in the era of reconciliation. Hence the belief in supernatural revelations as the basis of religions may also be increasingly given up as time passes. It certainly seems to be losing ground at present. What will our grandchildren think about it?

We may here profitably quote again what was said fifty years ago by Bishop Temple, of London, regarding Darwinism. He came to think that it was more fitting for a Supreme Creator "to impress His will once for all on His creation, and to provide for all the countless varieties [of organic forms] by this one impress, than by special acts of creation to be perpetually modifying what he had previously made." This view of organic evolution may be rephrased so as to apply it to religious evolution, as follows: "It is more consistent with the modern understanding of the universe to suppose that moral progress is inherent in human nature, and that all such progress is therefore the result of a continuous natural evolution, than to ascribe it to supernatural revelations, those of later date modifying those of earlier date." Thus rationally interpreted, a new faith would arise when a prophet makes an acceptable modification of an earlier faith. The new faith would first appear in some limited area of the earlier faith; once established there, it would spread as far as it could into larger and larger areas; but as it spreads, new modifications, which we know as sects, would branch off from it; and they in turn would spread as far as they could. The faith of reverent science is one such.

The spread of new species of plants and animals from the areas in which they arise is controlled largely by geographical and climatic factors; the spread of new religious faiths—that is, of new species of belief—appears to be largely determined by racial mentalities, for the greater religions of to-day are rather closely related to the races of man. In view of this parallel between species of organisms and species of religious faith, the natural instead of the supernatural origin of religions may come to be more and more accepted by our children and theirs, just as we have come more and more to accept the natural instead of the supernatural origin of organic species.

How instructive it would be if we could obtain some definite measure of the rate of change of these opinions. A measure might be secured if a good number of churches of various denominations would cooperate, first, in preparing questionnaires on a variety of articles of Christian belief, and second, in asking their members to indicate their opinions of those articles. Replies would probably be of four kinds: Some church members might not have definite beliefs; let them remain in their uncertainty. Others might have definite beliefs but be disinclined to express them; let them remain silent. But the rest, and probably a good majority, would know and be willing to express their views. If such a census were taken every five or ten years for a century, we should be able to measure fairly well the drift of religious opinion in the census area. We could then learn something as to the rate at which descent is made from the long flight of theological steps, far up on which our grandfathers stood, and something also of the number of those who have reached the solid ground at the bottom of the flight, where they may hold the faith of reverent science. The value which such censuses would have in the future may be estimated by the value we should attach to them to-day if they had been taken during the last hundred years.

Another reflection concerns the value

that will be placed by future historians on the enormous change of religious beliefs which has been brought about by scientific study during and since the Victorian era. They will look back on this period as one in which many have liberated themselves from the centuries-long enslavement to the crude myths of an ancient and ignorant Asiatic people. The historians will see, as we also may see, in the long period during which the enslavement lasted, a measure of the astounding credulity of the human mind and of its incapacity to think out its problems by a reasonable, scientific method. They will see, as we indeed may see already, that confidence of belief and certainty of conviction do not suffice to prove the objective truth of the opinions so earnestly held. The historians will moreover recall the self-satisfied assurance with which the fathers of the church, while grossly ignorant of the natural world around them, believed they could solve the profoundest mysteries of the supernatural world, and they will contrast that assurance, as we may too, with the increasing mistrust which we moderns feel concerning the supernatural solutions reached by the fathers, in spite of our amazing increase of natural knowledge.

Those future historians will say our liberation from that centuries-long enslavement was tantamount to a declaration of independence, of as great moment in the spiritual world as the declaration of independence, which we Americans made in 1776 was in the political world. But the two declarations are unlike, in that the earlier one was definite in form, place and date, while the later one is indefinite in those dimensions. We can not, therefore, celebrate it by parades and orations and fireworks on a certain date every year, but it is nevertheless worthy of celebration, and I wish to outline a method of celebrating that spiritual declaration in a manner befitting its importance. This is the prognostication mentioned in my introduction.

Prognostication. Our declaration of spiritual independence can be best celebrated by a long festival of cooperation between the organized forces of religion and science—the priesthood and the professorhood—directed to the object which the priesthood has always, but the professorhood has not always held in view; namely, the betterment of humanity; and the festival must be continued into the future at least as long as the period of antagonism which so unhappily divided the two forces in the past. They may be ushered in during an era of brotherly love, vastly more truly Christian than the unhappy medieval era from which we have escaped, and therefore an era of enormous importance in human history; for the festival of cooperation should enlist all those members of the priesthood who, recognizing the victory of modern science over ancient theology, desire to replace a good share of their study of theological apologetics by a scientific study of the nature of modern man and of the methods by which he can be ethically moved; and it should enlist also all those members of the professorhood, who, still preserving their scientific methods but impelled by the faith of reverent science, wish to turn their studies toward humanity rather than to the further investigation of the non-human universe.

Let the attack on all those vast non-human problems be of course continued by such members of the professorhood as are not attracted to human problems; let the attack go on until all the island universes 300,000,000 light-years or more distant shall have been discovered and catalogued; let it go on until the almost infinitely minute electrons have been resolved, if they are composite, into their infinitely more minute constituents, as

atoms have been. Similarly, let all the more conservative members of the priesthood, who do not accept the results of modern science, continue their efforts toward human betterment by orthodox theological means. But it will be from this festival of cooperation, as it is entered into by more and more priestly and professorial members, that we shall expect the greatest progress in bettering humanity. Largely by such cooperation will appropriate scientific methods be applied, more than ever before, to the heavy task on which a theologically dominated religion has labored so long; for on that heavy task, if we may judge by the unscrupulous greed of our growing criminal class, and by the cheap complacency with which a still larger class seems to look upon the successes of the criminals, the long lasting labor has not been expended with great success. How can science *dare* to stand aside any longer, instead of taking a more active part *with* religion in directing its best efforts to the accomplishment of that greatest of all tasks? A reproach has been directed against Nero because he fiddled while Rome was burning. What will our descendants say of us of the professorhood who, assured of our salaries or our pensions, continue to work upon our recondite, non-human problems, while our neighbors suffer and our nation is criminally demoralized.

I am not unmindful of the efforts already made for betterment, nor would I overlook whatever measure of success those efforts have reached. In particular would I recall the historic fact that, even during the era of antagonism between theology and science, efforts for human betterment were made more largely by the priesthood than by the professorhood. Those efforts were, to be sure, guided by what we now consider mistaken beliefs, and they were too often directed by a wish to secure a verbal profession of faith rather than an actual performance of good works; but they had the high merit of being closely associated, all through the Christian era, with correction of error, relief from distress and consolation in affliction, as they are still. But as far as efforts of the priesthood toward ethical betterment are concerned, they have been, as a rule, too narrowly limited to precept and exhortation, without a sufficient use of what would, in scientific teaching, be called laboratory exercises. It is for that reason that we may have confidence in the attainment of a greater measure of ethical success in the future, when our efforts toward that end are guided less by theological than by scientific principles; and when those better guided efforts are applied not only through exhortation to the young people who go to church on Sunday, but also in a more practical manner to the larger numbers of them at school and college all through the week. A great change must therefore be made in our educational methods during the festival of cooperation. There was a time not long ago when the heads of colleges were, almost as a matter of course, chosen from the priesthood; and when the morals of the students were cared for by the required attendance at morning prayers every day and at church services once or twice every Sunday; in other words, morals were then taught by precept. That was a time when physics and chemistry, botany and zoology were also taught by precept. We have now come to a time when the heads of colleges are seldom drawn from the priesthood but more generally from the professorhood; and when the sciences are increasingly taught by laboratory exercises, in which actual performance is required of every student. Yet in spite of these scientific advances, *less* rather than *more* attention is now given in colleges to the inculcation of morals, perhaps because of an increasing consciousness that the old

method of inculcating them by precept was so ineffective. To be sure, elective courses are offered in ethics; but they are not very largely taken and they treat chiefly the ethics of peoples and races; or if individuals are mentioned they are usually famous persons, not mere boys who call themselves *men*.

This inattention to the local individual must be corrected. Just as physical health and bodily strength are increasingly secured for each student by the performance of appropriate bodily exercises in gymnasiums or on playgrounds, so ethical health and the building of finer characters must in the future be secured by the performance of appropriate exercises in what may come to be called an ethical laboratory; and such exercises will gradually penetrate downward from the colleges where they are developed into the schools. There is today a not unnatural unwillingness to have any one religious faith taught in the schools; there will be no such unwillingness shown regarding the practical inculcation of ethical principles, for ethical principles are substantially alike in all the religions professed amongst us.

But it is not only by downward penetration from colleges into schools that better methods of ethical education will be extended. They may also penetrate upward from schools into colleges. The efforts of an important movement, already developed among school-teachers and known as "progressive education," are directed toward discovering the best means not only of teaching children but of developing their finer qualities. What career, therefore, can be nobler than one in which men and women of real ability are thus not instructing children only in the rudiments of knowledge but are developing their loyalty to high ideals; for in that career those consecrated to it are not merely *earning* a *living* out of teaching, but are *spending* their *lives* on it. The discouragements in work of this kind will be many; assured successes will be long delayed and few. No immediate and definitive results, such as those which commonly attend investigations in physics and chemistry, are to be expected. Experiments in human betterment must last a lifetime. Hence only those of the professorhood should undertake betterment problems who desire, as the best of the priesthood have for centuries desired, to consecrate their lives to a task of uncertain rewards, yet a task on which the future of humanity must largely depend.

This proposed festival of cooperation may perhaps be decried as absurd, and its practical exercises in ethics may be deemed fantastic by doubting Thomases; but the cooperation is eminently feasible, and the practical exercises in ethics can and must be developed. Nowhere are they more needed than by the rising generation in our own country, where the lawless greed which so abounds in the grown-up generation excites astonishment, to say the least, among our friends in Europe, while our own inefficiency in correcting lawlessness, not to say our indifference to it, mortifies us so profoundly at home; for we are living in an era when professional politicians are increasingly governing us to their selfish satisfaction and to our disgrace, and when organized criminals, ingeniously sheltered from the law by expert legal advice, are to our shame conducting a more profitable business than any one else. We must surely during the festival of cooperation make a vastly more active and effective educational effort toward ethical betterment than we are now doing.

Our universities must come to recognize the need of such effort. They have grown enormously in the last century. Opportunity for study within them has been immensely broadened by enlarging

the equipment of faculties, laboratories and libraries. Direction and supervision of study is so much improved that scholarship has risen gratifyingly in spite of the many distractions that tend to lower it. Let the next step in advance be that of character-building. Let courses in practical ethics be introduced, tentatively at first, with more confidence later on. Perhaps some such courses are already established, but they are not yet usual, as they must come to be.

Imagine a general introductory course of 100 or more students. At its close let the professor in charge invite a promising group of its members to go on with him for another year in an avowedly experimental course, in which all shall agree to study each other, all to estimate the strength of various ethical qualities possessed by each, and then jointly to devise practical exercises which shall strengthen the weaker qualities. Something valuable would surely be learned after ten or twenty years of such experimentation in ten or twenty colleges; and from that beginning further steps might be taken. For remember, our festival of cooperation is to go on for centuries. When the planning of these exercises is under discussion, all persons should be excluded who say at the beginning that such exercises can not be successful. Plans should be made only by those who insist that at least some exercises *can* be and *shall* be successful. Above all, let no one say, "Human nature can not be changed." It has already been enormously changed and it is going to be changed more still. Every ardent disciple of Christ must believe that. Could any university president have a higher ambition than to see, during his administration, the successful development of wholesome courses on character-building, as a fitting supplement to the broadening of opportunity and the raising of scholarship by his predecessors?

Mistakes will be made, of course, but mistakes can and will be corrected. The most manifest will be the development of self-conscious priggishness; that must be avoided by the cultivation of a truly Christian humility. It is already known that profitable elementary exercises in ethics may be introduced unconsciously in games and sports; witness the expression, "It isn't cricket," by which meanness and under-handedness are condemned in England, the home-land of fair play. We may build much farther on that beginning. Let the ability, the inventiveness, the perseverance which have characterized progress in nonhuman sciences be applied practically in ethical science and it will then advance as it never has yet; but it must not be expected that the advance will be rapid. No one may know to-day the most effective methods of forming habits of self-control and self-sacrifice, up to a truly Christian standard; but better methods will surely be discovered by scientific study and experimentation. Such study may even teach us how to do unto others as we would that others should do unto us; and when we learn how, let us call that great principle "the rule of unselfish happiness," not the "golden rule." Golden is not a good enough name for it.

The development of school and college courses in practical ethics should not, however, be by any means the only object of the festival of cooperation. The festival should be so conducted that it will attract large endowments for the investigation of the best methods of advancing human betterment, in order to aid in the development of school and college courses. We have such endowments already for various objects of a somewhat like nature. One of them is endeavoring to stamp out certain diseases at their source. Several endowments are studying the means of pro-

moting public health. We have various excellent organizations for practical betterment, such as eugenic societies, institutes of family relations, and so on. Some investigators are striving to discover the cause and cure of cancer. But most of these are working collectively on the human body; few are working on individual human natures. May we not therefore hope that future endowments shall be more directly applied to the discovery and cure of the mental disorder known as selfishness, which lies at the very root of so many of our disorders. Surely that mean and degrading quality is more damaging to humanity than cancer is! The wonder should be that a concerted, scientific attack on it has not been already made. Is the delay perhaps due to an aloofness of the professorhood because of a semi-conscious but mistaken feeling that the correction of moral faults is the business of the priesthood? If so, let us hope that the mistake will be soon corrected; not that the priesthood shall cease their efforts but that the professorhood shall helpfully cooperate with them. How wholesome it will be to bury the acrimonious disputes which separated those two great forces in the past, under the cordial relations of the future. Can there possibly be a nobler crusade than one formed by the union of those forces marching unitedly against the defects of humanity? If our defects are due to our glands, then let the crusade march against the glands!

But let it be understood that the crusade is not to be begun by proclamations calling attention either to it or to its object. It will begin inconspicuously; it has undoubtedly begun already in various quarters. But it is at present everybody's and therefore nobody's business. What it now needs is organization and direction; and it is in supplying that need that a long-lasting endowment for coordination will be immensely useful; an endowment directed by men of constructive and persuasive wisdom, who would give their whole time to it and who would, for years and years to come, encourage and focus on a central object the many lines of religious and scientific effort which are now pursued too independently for the greatest efficiency. Can this association, which is pledged to the advancement of science, possibly do better work than promote the establishment of such an endowment? Is there anything in the world more important and more difficult to work upon than the improvement of human nature? Can science anywhere find a more worthy subject for investigation than the methods of accomplishing such improvement? As an encouragement to persevere against difficulties, let us remember again that we live in a world which was merciless for ages and ages, but a world in which the quality of mercy was developed, not many centuries ago, by unconscious evolution; a world in which a sense of justice has similarly arisen, telling us that might is no longer right, although it truly used to be right. If so much has been gained by unconscious evolution in the last few thousand years, how much more may we hope to gain from conscious evolution during the plenitude of time to come!

Reference to science has often been made in this address. Let us be careful to understand that there is no mystery or magic about it, in spite of its enormous power. Science is merely *well-attested knowledge*. Let no one make the mistake of imagining that it is hard or unfeeling. In tasks where vigorous action is needed, it works with active vigor; in those which call for gentle sympathy, it is gentle and sympathetic. Its faithful handmaid, logic, will be deemed cold only by those who like to repose on mossy banks of outgrown beliefs in shady groves of tradition, for

naturally enough such slumberers do not wish their repose disturbed by the clear light of truth. The fields of science include everything that can be observed; for example, human conduct: human conduct being merely one of the many problems which finds a better explanation under the scientific philosophy of natural evolution than under the credulous theology of supernatural creation. The results of science are not final or absolute; they are always open to correction and extension. The essence of its spirit is a search for truth, by which, as an old philosopher long ago said, *no man has ever yet been harmed.* That search has been wonderfully successful in the physical world. Great renown has come to members of the professorhood through their discoveries, even if what they have discovered is as utterly remote, as utterly beyond application to the betterment of humanity as the dimensions of the orbits of a binary stellar system, the two members of which have never been seen apart even in the most powerful telescopes. True, such discoveries *do* teach us more of the mystery of the universe as well as of the possibilities of achievement by the human mind; but unfortunately, the privileged few who have the time and the ability to achieve such discoveries and to appreciate their meaning constitute almost a secret order, far above and regrettably apart from the ordinary run of mankind. By all means let those distinguished members of the great professorhood go on and discover new marvels in the physical world and the astronomical universe, but may we not hope to see, alongside of them and equally honored with them, another group of the professorhood who shall apply themselves with equal ability and assiduity, and in harmonious cooperation with a liberalized and growing group of the priesthood, to solving the everyday terrestrial problems of selfish humanity? Many difficulties lie ahead. Progress will be slow at best. But surely we may look forward with confidence to bettering days when our festival of cooperation is well under way. For my own part, and I trust for many others also, the ground for that forward-looking confidence is an optimism which is based on a study of the past and which springs from a firm belief in the philosophy of evolution and the faith of reverent science.

ON THE ABILITY OF WARM-BLOODED ANIMALS TO SURVIVE WITHOUT BREATHING

By Dr. LAURENCE IRVING
DEPARTMENT OF PHYSIOLOGY, UNIVERSITY OF TORONTO

THE need for oxygen is the most insistent requirement for human life. It is quite different from the requirements of food and water, which need satisfaction only at intervals which may be quite prolonged without discomfort. If man is deprived of oxygen for a minute his situation becomes quite intolerable, and if the period of deprivation is only slightly extended consciousness is lost and life soon ends. The brevity of duration of life without oxygen leaves only a narrow margin of oxygen reserve to separate life from death.

This narrow margin of oxygen reserve between life and death has been of great importance in determining human activities and behavior. The usual termination of life comes as the result of interruption of respiratory activity. Only one link in the chain of processes which secure the continuity of respiration need be broken, and the processes by which respiration is effected are delicate. The peril of death is always imminent from the disturbance of respiratory functions, and the preservation of respiratory activity is secured by giving precedence to its reflex control. If respiration is forcibly arrested, the most violent of all possible physical struggles ensue, at first directed toward relief of the obstruction, but rapidly becoming incoordinate. Even a decapitated animal which has been kept alive by artificial ventilation shows violent though incoordinated struggles upon cessation of oxygen supply. It is no exaggeration to say that the matter of securing a constant and adequate supply of oxygen is a constant preoccupation during life.

The period during which man can suspend respiration has influenced many of his separate activities. It must be allowed for in musical notation and determines the length of spoken phrases. Respiratory movements interfere with the most delicate manipulations and may be voluntarily restricted for a short time. Restraint of respiratory movement is likewise a condition for extreme attention to the perception of faint odors or sounds. It is also the respiratory requirement which restricts the ability of man to be submerged, and sets the limits of time and depth to his natural means of submarine exploration.

Most warm-blooded animals resemble man in the shortness of the time for which they can remain submerged, and yet there are certain diving animals which notably excel the ordinary terrestrial forms. These diving animals are not restricted to a single small group, but appear among several orders of birds. Among mammals, besides the aquatic manatees, whales and seals, there are, for example, the muskrat and beaver, the hippopotamus and the otter.

In order to examine the proposition of what limits the ability of man for submergence and what apparently extends that ability in certain other animals, we can begin to examine the capacity of man.

If respiration is temporarily arrested, the period for which any one of us can hold his breath without extreme discomfort is limited to forty-five seconds. If, however, some previous preparation is made by forced deep breathing, that period may be extended to five or six minutes. If to that preliminary period of deep breathing is added the respiration of oxygen, the time may be ex-

tended to a total of 10 or 15 minutes. The latter device was made use of in the preparation of sprint swimmers in the recent Olympic games and gave to the users a distinct advantage on account of longer freedom from the necessity for respiration.

The rate of oxygen consumption is one factor which determines the period during which a man can hold his breath. For a person at rest we can take the oxygen consumption to be 250 ccm per minute; with only quite moderate activity, such as walking, 7–800 ccm per minute are required. For heavy work, such as mountain climbing or other violent exercise, the consumption may rise to from 1,500 to 2,000 cc per minute. A Marathon runner traveling at seventeen kilometers per hour consumed as much as 3,500 ccm per minute.[1]

Against this demand we find that the ordinary individual has certain capacities for the storage of oxygen. Storage in the lungs is the most obvious reserve. This so-called "vital capacity" amounts to about 10 per cent. of the body weight; 70 kilograms body weight would thus contain 7 liters of air. Of the 7 liters of air, about one fifth would be oxygen and would afford about 1,400 ccm of oxygen. Furthermore, a certain amount of oxygen would be stored in the blood. Allowing approximately 7 per cent. of the body weight as made up of blood, with an average oxygen content of 17 ccm per 100 ccm of blood, we find that the total quantity of oxygen in the blood would be about 830 ccm.

In addition to these more apparent stores of oxygen, there are other body fluids which are more or less saturated with oxygen. The degree of oxygen saturation of the tissue fluids is a matter of some doubt, but it can scarcely be greater than one half, and the corresponding quantity of dissolved oxygen would be about 600 ccm.

These three reservoirs of oxygen in the human body together provide a maximum store of less than three liters. Actually it is quite impossible that the entire quantity would be available for use; for there must always be maintained a certain gradient which serves to force the oxygen from the places where it is stored into muscles and other tissues, where it is to be consumed. Probably not more than one half the total stored oxygen would be available for use when respiration was arrested. This would amount to about 1,500 ccm. Since the oxygen requirement at rest is 250 ccm. per minute, the reserve would seem to allow for survival at rest without a new oxygen supply for as much as 6 minutes. That is just about the period of survival if the oxygen consumption is maintained at the low resting level by anesthesia. Beyond that time the flame of human life is low and uncertain.

It is also true that, in addition to the store of oxygen that is dissolved in tissues and blood, there exists an important mechanism which is capable of maintaining the muscle tissues during a period when oxygen is not available. It depends upon the ability of the muscles to transform glycogen into lactic acid without the intervention of oxygen in the process. The reaction yields energy which can be applied to carry on muscular activity. At the expense of the glycolytic reaction, muscular activity can be accelerated far more rapidly than the processes which supply the muscles with oxygen. The limit is soon reached, however, and before complete recovery occurs the products of glycolysis can only be restored by the use of extra oxygen. For this reason, the processes of brief intense muscular activity develop an oxygen requirement in the body which is designated as an oxygen debt. It is not, however, like a national debt, for it has precise limits and must be repaid in terms identical to those under which it was incurred.

The repayment of the oxygen debt is indicated by an extra consumption of

[1] F. A. Bainbridge, "The Physiology of Muscular Exercise." London, 1931.

oxygen during the recovery, and it is measured in terms of this extra oxygen consumed. For a trained athlete such as a sprinter the debt may amount to as much as 15 liters of oxygen,[2] and it indicates the existence of an energy reserve for muscular activity equivalent to the energy which would be derived from the utilization of 15 liters of oxygen.

In contrast to the total stored oxygen of 3 liters, 15 liters is quite a large amount, and one would be inclined to turn to this device in order to provide means of survival when respiration is arrested. But this method of metabolism is, as far as we know, available only for muscular activity and is not extensively utilized by any other tissue than muscle. So that while the oxygen debt may serve very well to carry on muscular activity during a short period of asphyxia, it does not solve the problem of an energy supply for the other tissues. Perhaps it is on account of the lack of means to develop an oxygen debt that the heart and brain are particularly susceptible to asphyxia.

The various means which have been proposed are not capable of maintaining survival during extended periods of asphyxia, and we can scarcely see how it would be possible for a human animal to survive for more than a few minutes. Many animals, on the other hand, are superior to man in this respect. Probably the first systematic work on this subject was done some years ago by Paul Bert.[3] He determined the period during which a number of animals survived forced submergence under water. Various terrestrial animals, such as the dog, cat and hen, survived submergence for from 2 to 4 minutes. Similar examination of animals with a partly aquatic habitat, such as gulls, indicated that they were not superior to the terrestrial animals. But the ordinary domestic duck, not a highly developed nor actively aquatic animal, survived for a period of 10 to 15 minutes; a young seal (remarked upon as not in very good condition) was still moving at the end of 15 minutes, and the heart continued to beat for 28 minutes.

It is of interest to consider the further observations of Paul Bert on the marked ability of young animals to survive asphyxia. New-born rats would survive thirty minutes; for adults the limit of survival was about two minutes. During development the period which they survived progressively diminished. This remarkable capacity for resistance to asphyxiation in new-born animals he related to the necessity for sudden development at birth from a condition in which the respiratory apparatus had not been in use. During the time of birth in mammals there must occur a more or less prolonged period when respiration is quite impossible. Respiration then starts rather hesitantly and only after some time does it become regularly and firmly established, and during its earliest life the young mammal can easily endure asphyxia for periods which would later be fatal.

The experiments on forced submersion would appear to be rather artificial and would scarcely give the animal a fair chance to demonstrate its full ability to endure asphyxia. On looking through the literature to ascertain the opinion of the various authors on the duration of the period for which diving animals can remain submerged voluntarily, we find that good observations are scarce. Leonard Hill[4] has said that the human limit was probably that of a pearl diver, amounting to about 3 to 4 minutes, without any previous oxygen treatment. The record period he claimed for a skilled diver, who remained submerged and visible in a tank for nearly five

[2] *Ibid.*

[3] Paul Bert, "Leçons sur la Physiologie Comparée de la Respiration." Paris, 1870.

[4] L. Hill, "Caisson Sickness and the Physiology of Work in Compressed Air," pp. 8–16. London, 1912.

minutes. Professor Parker[5] observed the respiratory periods of the Florida manatee in an aquarium, and the longest interval between respirations was 16 minutes and 20 seconds.

Beyond these few observations we find what seems a singular hesitation on the part of naturalists to state how long a diving animal can or even does submerge. The beaver can swim under water for about five minutes, according to Ernest Thompson Seton's[6] calculation from the statements of the old trappers. The ability of diving birds has probably been overrated on account of their skill at concealment when emerging. Mr. Arthur H. Norton, curator of the Portland Society of Natural History, sent me a number of observations, and the longest records were those of the loon and old squaw, with about 40 seconds' submergence. And yet the Great Lakes fishermen tell of old squaws caught in nets at the depth of 180 feet (according to a communication from Dr. Remington Kellogg), and there are stories of the capture of loons on set lines at considerable depths.

It seems singular that observations of so interesting and important a nature are not more frequent. Trappers and guides, who live by keen and accurate observation of wild animals, will scarcely venture an absolute opinion on the subject, and reserve their comments for those times in camp when the vivid interest of a story takes precedence over the limitations of truth.

For over two centuries seals and whales have been systematically hunted, and the accounts of the pursuit quite properly form an extensive and fascinating literature. But as a consequence of the difficult conditions for observation and the romantic flavor which is so easily attached to whaling stories, we find that reliable authors show a good deal of hesitation in committing themselves as to just how long a whale can remain submerged. The longest story which I have encountered attributes to the Rorquals the ability to remain submerged for from eight to twelve hours.[7] Among the accounts of more cautious naturalists who have actually timed the dives, I find the observations listed in Table 1, that indicate the duration of submergence which the authors have actually observed and the longer periods, which, in the opinion of whalers, seem to be within reason.

The most interesting description of the ability of a whale is that of Captain David Gray,[8] commander of the whaling steamer *Eclipse*, in a description of the

TABLE 1

PERIODS OF SUBMERGENCE OF WHALES

Kind	Diving periods: observed	Diving periods: from opinions	Author
Humpback	20 min.		Andrews[9] 1909
Finback	23 "		
New Zealand Humpback	7 "	1 to 2 hours	Lillie[10] 1910
Fin whale	20 "	45 min.	Ommanney[11] 1932
Finback	10 "		Allen[12] 1909
Bottle nose	2 hours		Gray[13] 1882
Sperm		1¼ hrs.	Beddard[14] 1900
Greenland right whale	1 hour 20 min.		Scammon (from Beddard 1900)

[5] G. H. Parker, *Jour. Mammalogy*, iii: 127, 1922.

[6] E. T. Seton, "Life Histories of Northern Mammals," i, 475. New York, 1909.

[7] R. Collett, *Proc. Zool. Soc. London*, p. 263, 1886.

[8] D. Gray, *Proc. Zool. Soc. London*, p. 726, 1882.

[9] R. C. Andrews, *Bull. Am. Museum Nat. Hist.*, xxvi: 213, 1909.

[10] D. G. Lillie, *Brit. Mus. Nat. Hist. Reports*, British Antarctic (Terra Nova) Expedition. Vol. i: part 3, 1910.

[11] F. D. Ommaney, Discovery Reports, v: 327, 1932.

[12] G. M. Allen, *Memoirs Boston Soc. Nat. Hist.*, Vol. viii: No. 2, 1916.

[13] *Op. cit.*

[14] F. E. Beddard, "A Book of Whales." London, 1900.

bottle nose whale presented to the Zoological Society of London.

> They have great endurance, and are very difficult to kill, seldom taking out less than three to four hundred fathoms of line; and strong full-grown males will run out 700 fathoms, remaining under water for the long period of two hours, coming to the surface again as fresh as if they had never been away; and if they are relieved of the weight by the lines being hauled in off them before they receive a second harpoon and a well-placed lance or two, it often takes hours to kill them. They never die without a hard struggle, lashing the sea white about them, leaping out of the water, striking the boats with their tails, running against them with their heads, and sometimes staving the planks in, frequently towing two heavy whale-boats about after them with great rapidity.

From these various accounts we can conclude that certain mammals have a capacity to resist asphyxia which far exceeds the ability of man, and, as a matter of fact, exceeds the capacity which we would expect on the basis of the amount of oxygen stored. That being the case, then, we might consider what modifications occur in these animals which would adapt them to survival. One might be an increased vital capacity with an increase of oxygen stored in the lungs. This capacity might possibly be doubled; on the other hand, if it were to be much more than doubled there would hardly be space available in the body to accommodate the other organs. Birds in particular have a very extensive respiratory apparatus, but when Mr. Foster and I examined the vital capacity of the duck, we found that it was only about double that which would be expected in a mammal of the same size. The hen has nearly as great a vital capacity as the duck, and yet is quite inferior even to most mammals in ability to resist asphyxia. Even doubling the vital capacity stores only sufficient oxygen for another minute or two of resting metabolism. So it is not possible to account for the superior ability of diving animals by greater air storage.

An increase in the volume of blood might be considered. Many authors have called attention to the peculiar vascular devices common among aquatic animals, the *retia miriabilia* or networks of blood vessels, which are often quite extensive and which would seem to give to the animal a greater capacity for blood and hence for oxygen storage in the blood. By determination of the blood volume by means of vital red injection Mr. Foster and I found that the blood volume of the duck and muskrat were about 10 per cent., somewhat greater than is usually found for mammals. But again the hen was nearly as well provided with blood.

It is unlikely that vital capacity and blood volume could both be doubled, for they would then occupy some 35 per cent. of the body, scarcely leaving room for the other organs. Even such an increase would only provide the capacity for a few minutes' longer survival without respiration. If, then, we could give the animal only a slight addition to its ability to survive, making the limit three or four minutes instead of one or two, it would not seem worth while to consider these modifications in the respiratory or circulatory system as sufficient to adapt an animal like the whale to attain its great ability for submergence and under-water activity.

We should also consider the possibility of increasing the capacity for muscular oxygen debt. That seems at first sight a tempting possibility to investigate. But an increased capacity for developing an oxygen debt implies a superior buffering capacity in the muscles. To postulate a large variation in such a fundamental chemical property of muscle is rather dangerous, for we know that the principal chemical properties of all vertebrate muscle are essentially alike. As an indication of buffering capacity of the muscle, we have examined the carbon dioxide content of the muscle of ducks and muskrats, and found them

similar to the muscles of cats and dogs. Furthermore, if we were to increase the oxygen debt forming capacity, it would only influence the capacity for maintaining muscular activity for a longer period of time. It would not help the heart and brain to survive.

I do not think that the difficulties of non-diving animals rest in the preservation of the skeletal muscles; the oxygen supply for an arm or leg may be cut off for from 10 to 15 minutes without discomfort, and for much longer than that without actual injury to the part. More difficulty seems to arise in protecting the more sensitive tissues, such as the heart and brain, which are so sensitive to asphyxia.

It often happens that when we examine an animal part by part and then attempt to recreate the whole by the addition of parts, we find that the whole animal is quite different from the sum of its component parts. There are certain relations according to which the parts are made to cooperate, a peculiar type of integration which completes the working organism in a manner which is not by the simple addition of functions. The mechanism for the control of this integration we regard as the central nervous system. Perhaps we are likely to call it behavior, if we are of one type of biologist, or, examining the process as physiologists, we are inclined to analyze this behavior into its component parts, and refer to them as reflexes. It seems possible that it might be pertinent to examine some of the reflexes of diving animals to see whether they may be responsible for some degree of protection against asphyxia.

The first definite information which appeared was published again by Paul Bert[15] on the behavior of ducks when forcibly immersed in water. They remained quiet and passively endured asphyxia for from 12 to 15 minutes. This behavior is quite in contrast to that of terrestrial animals, which, when submerged, or when the trachea is clamped, immediately perform convulsive movements which violently attempt to relieve the animal from the cause of asphyxiation. The movements soon become quite purposeless and actually serve to accelerate exhaustion and death. The duck, on the other hand, conserves its energy by eliminating all muscular activity.

The process of inhibiting muscular activity has been definitely worked out as a reflex reaction, aroused by postural stimuli which give the inhibition even when the animal is out of water.[16] By holding the head and neck of a duck in a certain position, resembling the one assumed when under water, that is, with the head and neck extended and slightly depressed, all activity of the animal ceases. The same sort of reflex inhibition of muscular activity can also be seen in the muskrat under a stimulus of the same kind. Activity of the respiratory muscles is inhibited as well, and respiratory movements are at once abandoned. A duck or muskrat can be held in that position for several minutes and no attempt to breathe will be made. That type of reflex is obviously of an adaptive nature in conserving the energy of animals for existence under water.

Along with the depression of muscular activity and the cessation of the working of the respiratory system, the following significant observation was made by Richet.[17] Inhibition and retardation of the heart beat occurred by stimuli transmitted through the vagus nerve. When the vagus nerve in a duck was cut or inhibited with atropine it survived no longer than a hen would under the same conditions. This reflex mechanism then has a definite conservative

[15] *Op. cit.*

[16] F. M. Huxley, *Quart. Jour. of Exp. Physiol.*, vi: 183, 1913.

[17] C. Richet, *Jour. de physiol. et de pathol. gén.*, i: 641, 1899.

effect in protecting an animal during diving.

Even so, while it may inhibit the activity of the animal, it can not abolish its basal metabolic requirements, and we are still faced with the problem of how these animals survive for as long a period of time as they do. A hint comes from the observations of Gratiolet,[18] who described the vascular structure of the hippopotamus. He claimed that there was a muscular band which passed around the vena cava about where it went through the diaphragm. He believed that it had the ability to contract and to prevent the remainder of the blood from passing into the heart from the posterior circulation. He thought that such a mechanism would be useful in preventing the engorgement of the heart and brain which were supposed to occur in asphyxia. The idea of "engorgement," however, may be injected into consideration by reason of subjective sensations during asphyxia, when the cerebral vessels seem to be engorged and the heart feels full; but it is doubtful whether the blood pressure is actually elevated in these organs. On the other hand, if such a device were to shut off a large part of the returning systemic circulation, then it would be possible for such oxygen as was stored in the lungs and blood to be utilized by those organs which are particularly sensitive to oxygen want. The muscular tissues could get along with the help of the oxygen debt process, but the heart and brain require some device to aid them.

In recent years more and more attention has been paid to the cerebral and coronary circulations, with the result that it is apparent that control of those systems is quite distinct from the type of control exerted over the ordinary systemic circulation. We find suggestions of this in the apparently opposite action of histamine and adrenalin on coronary circulation. We learn further, from Lenox and Gibbs,[19] that if carbon dioxide is administered to the extent of from 5 to 10 per cent., and the cerebral circulation is judged by the amount of oxygen in the blood returning through the jugular vein, its circulation will be accelerated by as much as 40 per cent., while the circulation through the femoral vein is diminished. There is then a relation between the cerebral and systemic circulation, which under conditions of asphyxiation may serve to conserve the blood and oxygen supply for the more sensitive tissues at the expense of the others.

I feel that when we can find neither chemical nor physical processes in the avian or mammal body which would adapt them for submergence, that we should turn our attention to reflex adjustments. It might be pointed out that the physical and chemical properties of the muscles of mammals and of all vertebrates are remarkably alike; the blood apparently has the same characteristics in all forms, and the elements of the nervous system are so similar as to be practically indistinguishable. So we might remark that during the operation of the forces of evolution the physical and chemical characteristics have remained relatively fixed, maintained in an apparently rigid mold. On the other hand, the adaptation of various groups to different environments indicates a remarkable degree of plasticity in the nervous system. In the integration for use of these essentially similar organs arises the capacity for adaptation.

[18] M. P. Gratiolet, C. R. Acad. Sci., Paris, li: 524, 1860.

[19] W. G. Lennox and E. L. Gibbs, *Jour. Clin. Invest.*, xi: 1155, 1932.

A STORY OF THE SHRIMP INDUSTRY[1]

By ELMER HIGGINS

CHIEF, DIVISION OF SCIENTIFIC INQUIRY, U. S. BUREAU OF FISHERIES

SYMBOLIC of the diminutive and the trivial as an individual, the shrimp as a tribe are far from inconsequential, for the three important species taken from North Carolina to Texas have yielded an annual catch valued to the fishermen in a raw unprocessed state at nearly four and a half million dollars. As a source of food, whether served as the familiar cocktail or as salad or in such marvelous concoctions as à la Creole or jambalaya, the shrimp rivals the sacred cod or the mackerel of the North Atlantic, is half again as productive as the tunas or all the flounders, yields twice as much as the Pacific halibut and eight times as much as the lobster. As a matter of record, in 1929 the shrimp fishery ranked ninth in volume but fifth in value among all the fisheries of the United States. In fact, if all the little shrimp caught in that year were placed head to tail in a straight line, it would take a lot of work. And a lot of work was performed in the 69 canneries of the South, where 1,371,502,720 individual shrimp (or thereabouts) were headed by hand and canned into 818,491 standard cases worth $4,960,542.00, according to the government's published statistics (1930).

Although I had seen something of the shrimp industry in the South, I now feel that I have made almost personal acquaintance of a good many million individual shrimp after viewing acres of them on drying platforms and seeing tons of them unloaded at canneries during the first days of the autumn fishing season in Louisiana. I have recently returned from a trip through the heart of shrimp land—from New Orleans to the Gulf through Barataria Bay—for Louisiana produces 45 per cent. of all the shrimp taken on the South Atlantic and Gulf coasts, which in turn is 95 per cent. of the production of the entire country.

I arrived in New Orleans with the intention of reviewing the program of research upon the shrimp and the shrimp industry undertaken cooperatively in the interest of conservation by the U. S. Bureau of Fisheries and the Louisiana Department of Conservation. As a part

[1] Published by permission of the Commissioner of Fisheries.

THE "FATHER OF WATERS"

IN NORMAL STAGES IS SO BROAD AND PLACID BELOW NEW ORLEANS THAT, AFTER THE FIRST THRILL OF MEETING, IT BECOMES AS UNINTERESTING AS A BRACKISH WATER COASTAL SOUND.

SHRIMP OF THE GULF AND SOUTH ATLANTIC COAST

Penaeus sitiferus, THE COMMON SHRIMP OR LAKE SHRIMP OF THE GULF AND THE SHRIMP OR PRAWN OF THE SOUTH ATLANTIC, YIELDS 95 PER CENT. OF THE TOTAL CATCH OF SHRIMP OF THE REGION. TWO OTHER SPECIES ENTER THE COMMERCIAL CATCH IN VARYING QUANTITIES. PHOTO BY J. N. GOWANLOCH.

of this review I had planned to observe fully all the various activities, including those performed at sea by the investigative staff. So it was that I spent two days in conferences with state officials and the federal bureau's staff—spent them a little impatiently anticipating the sea trip aboard the bureau's research vessel, *Black Mallard*.

By this time, the captain had the *Black Mallard* ready for us and well provisioned for the run down river to Southwest Pass, so we left on Friday afternoon for an uneventful run on the broad breast of "Old Man River" through a golden sunset to Pilot Town, where we spent the night aboard and started early the next morning for the pass. Trawling for shrimp was to be done in East Bay, a wide expanse of shallow water enclosed between the outspread arms of low-diked river mouths, but stormy weather threatened to disrupt our plans. A brisk southeast wind on Saturday morning whipped the surface of East Bay into foamy whitecaps, making it impossible to work with fragile silk nets searching for baby shrimp. Finally a Coast Guard radiogram received at Burrwood, warning of the approaching Gulf hurricane that ten hours later swept Galveston, convinced the captain of the futility of waiting for the wind to lay, so we put about and retraced our course a hundred miles up the winding river channel to New Orleans in order to reach the gulf and sheltered Barataria Bay by another route.

The return trip was also uneventful.

but it gave our scientific personnel an excellent opportunity to discuss length frequencies, growth rates, appearances and disappearances of the shrimp, water temperatures, salinities and hydrogen-ion concentrations, and all the other voluminous data that are part and parcel of a scientific study of the life history of the shrimp. Between such sessions we idly watched heavy-winged white herons rise from the river bank ahead of us, straighten their long legs and flap slowly up river to alight at the water's edge and await our approach only to repeat this senseless retreat again and again.

After spending the night in the mouth of a shallow canal, well screened from singing mosquitoes, we continued our run again early Sunday morning. Finally the low roofs of scattered farmhouses nestled behind the unending levees gave place to docks and factories with tall stacks as we approached the city, and we entered Harvey canal beside the bigger and better locks that will replace the ancient ones now holding back the river when in flood stages.

Running down the canal past the Hero pumping plant, which drains the surrounding country, dodging in and out between slow-moving barges, we entered a section of Louisiana filled with romantic legend and haunting beauty, and traversed winding Bayou Barataria southward toward the Gulf. As we passed, brown water from the swamp sucked and whirled among the buttressed trunks of majestic cypress or spreading live-oaks, festooned with garlands of Spanish moss, and over the green wall of the bordering forest glistened towering thunder-heads, portending dashes of summer rain. Past solitary cabins of the moss gatherers, past the scattered hamlet of Barataria we slipped and viewed the village reputed to be the rendezvous of Louisiana's Robin Hood, the pirate LaFitte. Here we encountered solid meadows of floating water hyacinth, blue-flowered and lovely. They are cordially hated by the watermen because they grow so dense as seriously to impede navigation. For an hour we plowed through the "lilies," not yet destroyed by the U. S. Engineer's poison sprays, making only four miles; and so dense at times were the waxy leaves and air bulbs that one of our party in a spirit

A LIKELY NURSERY GROUND

HERE WHERE FOREST AND MARSH MEET MAY BE AN IMPORTANT NURSERY GROUND FOR THE LOUISIANA SHRIMP SUPPLY.

CYPRESS SWAMPS

BORDER BAYOU BARATARIA EN ROUTE TO THE GULF. SINCE EARLY TIMES MOSS PICKERS LIVING IN ISOLATED CABINS THROUGH THE SWAMPS OF LOUISIANA HAVE GATHERED SPANISH MOSS FOR MANUFACTURE INTO MATTRESS FILLERS. ON THE GULF COAST THE ANNUAL CROP BRINGS TWO AND A HALF TO THREE MILLION DOLLARS.

of bravado jumped overboard and walked about on the masses under our bows. Threading Dupré Cutoff, where stand occasional patches of "Ghost Forest," stark and naked trees killed by occasional invasions of salt water in times of unusual drought, we met the marshes, empty stretches of waving saw-edged grass lying lonely and desolate. These are the quaking prairies—"praire tremblante" where beneath one's feet the matted and rotting vegetation trembles on the sodden silty undersoil. Here muskrats build their homes, water-fowl nest and even occasional 'gators lurk. Pressing on, we entered the broad and winding marsh-bordered Bayou St. Denis and sighted the row of beacons in Barataria Bay which we must round before heading for the lights of Manila Village, our anchorage for the night.

After two and a half days of steady running with long hours for the vessel's crew, Monday, which was to be a work day for the scientific staff as well, dawned pink and opalescent upon a glassy bay. We were off early, running southward toward the entrance to the Gulf of Mexico. Manila Village and Cabanash, huddles of red buildings perched on piles above the marsh and surrounded by wide platforms for drying shrimp, were seemingly asleep, for the shrimp vessels had already left and shimmering in the mirage on the horizon—forty-six within sight at one time—were busy hauling their shrimp trawls.

From the center, Barataria Bay is a huge expanse of water stretching to the horizon on all sides, but dotted here and there with low grassy marsh islands or headlands sometimes spotted with *cheniers* or clumps of low oak trees. Actually it is but 12 miles long and somewhat wider but very irregular in outline and

LIVE-OAKS

ALONG DUPRE CUT-OFF NEAR THE OLD RETREAT OF THE PIRATE LAFITTE NOW SHADE SUMMER HOMES.

very shallow. Like the other numerous bays of the Louisiana coast it has a soft mud bottom, thus providing an ideal environment for shrimp and small fish. The water is brackish, because of the heavy rainfall and outwash from the swamps and marshes, and because it is so shallow the temperature rises to 90 degrees or so during the summer. On the Gulf coast there are but two tides, one high and one low each twenty-four hours, but these have less effect upon water levels or water currents, except in the vicinity of the passes, than the winds which often bank up the water on the windward shores until it overflows the marshes. Seaward, Barataria Bay is separated from the Gulf of Mexico by Grand Terre and Grand Isle, low-lying sand islands not unlike the barrier beaches of the Florida and Carolina coasts. In places trees with wind-clipped billowing tops shelter straggling communities of fishermen's houses, as at Grand Isle; and at the pass, Grande Terre rears a lofty eminence of forty feet or more, topped by historic old Fort Livingston, built in about 1814 and now, buffeted by southeast storms, crumbling and slipping brick by brick to a peaceful oblivion beneath the ninety-foot waters of the pass.

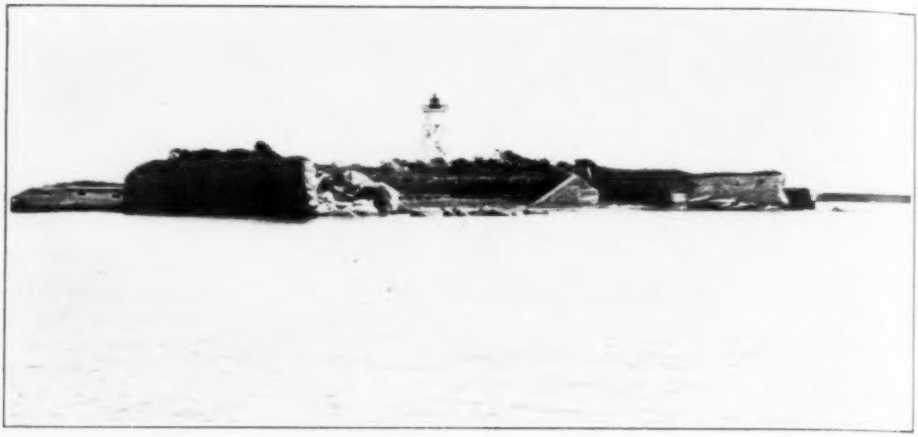
HYDROGRAPHIC OBSERVATIONS

IN THE GULF AND IN THE INLAND WATERS OF LOUISIANA WILL CONTRIBUTE TO AN UNDERSTANDING OF THE MIGRATIONS OF THE SHRIMP. HERE GOWANLOCH IS TAKING A WATER SAMPLE AND TEMPERATURE READING FROM THE BOTTOM.

THE SHRIMP TRAWL

IS BROUGHT ABOARD AFTER AN EXPERIMENTAL HAUL TO SAMPLE THE SHRIMP POPULATION IN BAYOU ST. DENIS.

Leaving the old fort and its stately landmark, Livingston light, the *Black Mallard*, feeling the long swell of the open gulf beneath her, heads south again to "twelve mile station," where periodic visits are made by the scientific staff for the purpose of collecting biological data on the shrimp and its habits. Reaching location where the lead showed 25 meters depth, the Greene-Bigelow water bottle with its reversing deep sea thermometers are put over at the forward davit and lowered to the bottom. After resting two minutes it is tripped by the sliding metal messenger, thus reversing the instruments, registering the water temperature and taking a sample of the bottom water, and then the whole



FORT LIVINGSTON

WITH THE PASSING OF PIRATES AND COLONIAL AMBITIONS OF FOREIGN GOVERNMENTS THE CENTURY-LONG VIGIL OF FORT LIVINGSTON GUARDING GRAND PASS HAS COME TO AN END.

apparatus is reeled in. Gowanloch squints at the delicate instruments and records the readings. Then the sample of water is drained from the instrument into a tagged glass bottle and set aside for salinity determination. A bit, however, is taken at once and placed in a color comparator to determine the pH, a measure of the acidity of the water.

While this is going on, the shrimp trawl is made ready and after the surface temperature and water sample is taken, the captain's whistle shrills "Stand by," as the vessel moves ahead. First the tail of the long bag-like net is put over the stern into the water, then the rest of the net goes overboard and Lindner and Gunter let go the otter

DOZENS OF VESSELS TRAWL FOR SHRIMP ON THE SMOOTH WATERS OF BARATARIA BAY.

boards and slowly pay out the towing lines. As the otter boards, hung like kites at the opposite sides of the net, catch the force of the water the net spreads out and settles to the bottom, the towing lines are made fast and the captain rings half speed ahead for the slow grind of an hour's hauling.

Immediately the plankton ring net is made ready and put overboard to tow at or near the surface from a special outrigger at one side of the boat. This net is a long conical bag one meter in diameter at the mouth made of silk mesh so fine that it will catch eggs or young of the shrimp or any other minute creatures more than 1/100 of an inch long. After towing for twenty minutes the plankton net is brought aboard and the catch is washed into a bottle and preserved for later study.

Soon the captain's whistle signals all hands to stand by for lifting the shrimp trawl. The gasoline winch slowly winds in the line, the boards are lifted aboard, the web of the net is hauled and if heavy it is swung aboard with a hoist from the boom. In this case the catch is light, however, and with only a moderate amount of heaving and puffing the boys land the catch by hand.

Spilled out upon the deck, our catch would have disappointed a shrimp fisherman. To the biologists, the catch provides a valuable record, for these men are prospectors seeking to find by persistent sampling just what kinds of sea creatures frequent this locality of the Gulf (and every other station visited) each week of the entire year. The shrimp of all sizes are quickly selected from the catch, whelks, crabs and other shellfish are noted and thrown overboard, and the fish are all sorted according to species, counted and recorded.

While the vessel proceeds toward the next station on its route the more exacting work proceeds. The shrimp are placed on the measuring table, where Gunter measures the length of each shrimp while Lindner records. In addition to the length, the sex and relative sexual maturity of each individual is noted, and a sharp watch is kept for those bearing the spermatophore, a structure involved in reproduction.

It is from the compilation and statistical analysis of the lengths of shrimp in hundreds of such catches and from catches of commercial fishermen as well that our biologists are able to deduce much of the life history of the species. Some hundred thousand measurements of shrimp from North Carolina to Texas have been thus analyzed. "Adding machine biology," some call it; others dignify it by the name of biostatics or biometry, and others lump it off as a part of fishery science. But science it is, for by such means is demonstrated

THE *BLACK MALLARD*

MAKES AN EXPERIMENTAL HAUL WITH STANDARD SIZE SHRIMP TRAWL IN BAYOU ST. DENIS.

that the two typical or "modal" sizes of shrimp present in any locality in the early summer are a year apart in age, that the smaller group just large enough to be caught by commercial gear are the young spawned during March, April, May and June, and that the larger group, the "Jumbo" shrimp, are the remaining few of the breeding class which, after spawning, disappear from the waters, never to be seen again,

doubtless dying after consummating life's destiny of reproducing their kind.

These length records demonstrate that growth is very rapid during the summer. Shrimp $2\frac{1}{3}$ to $3\frac{1}{2}$ inches long in July reach a size of $5\frac{1}{2}$ to 6 inches by September. They also show that the breeding season is long, for females bearing spermatophores are found in the outside waters of the Gulf as early as April and as late as August and even September. The records show that young during all these months and on into the fall are growing up to commercial sizes and are joining the schools of more mature individuals spawned earlier in the year to carry on the mystic dance of swimming and feeding that makes the shrimp so elusive and baffling to the fishermen.

But what makes the shrimp so notoriously erratic in its appearance and movements? Sometimes they are more abundant in the bays, sometimes in the Gulf. One day good catches will be made, and on the next no shrimp can be found in that locality but will be taken in abundance miles away. After cold storms larger shrimp may be caught where formerly small or mixed sizes abounded. Does the shrimp react to changing temperatures, seeking water of a congenial warmth? Does it retreat before an inflow of saline water from the Gulf, seeking a more brackish environment?

Undoubtedly the species reacts according to definite laws, to variations in its environment; and to discover by actual observations what reactions take place in nature under certain conditions is one object of the research program of the associated governments now under way. From these repeated observations,

THE RESULTS OF A HAUL

THIS CATCH WOULD BE DISAPPOINTING TO A COMMERCIAL SHRIMP FISHERMAN, BUT IT HELD VALUABLE DATA REGARDING THE ABUNDANCE AND DISTRIBUTION OF SHRIMP FOR GOWANLOCH AND LINDNER.

VESSELS AT NEW ORLEANS WHARF

TONS OF SHRIMP ARE LANDED DAILY AT THE CANNERIES IN LOUISIANA. THESE VESSELS, WITH THEIR CATCH ICED IN THE HOLD, HAVE MADE THE RUN TO NEW ORLEANS FROM BARATARIA BAY.

hypotheses will be prepared, and later after experimental tests have been made disproving, modifying or confirming our theories, we hope to discover and state some of the natural laws governing the shrimp's life, that now appears to be guided only by caprice.

Returning landward from our most offshore station, hauls were made at regular intervals entering Barataria Bay, in mid bay, at the head of the bay, in Bayou St. Denis and so on, in thunder squall and under broiling sun throughout the day. Detouring through Bayou Rigolets we reach Little Lake, dragging our keel through the soft mud bottom to a favorable place for anchoring.

After breakfast the following morning a seining party, consisting of the engineer, the four scientists and myself, made ready to go ashore to search for young shrimp—shrimp too small to be taken by the commercial nets. The stern motor was swung overboard and fixed to the dinghy; the seine, lined with fine silk mesh, was put aboard with the collecting bottles and thermometers; and after invoking dark powers in a few well-chosen words the motor started for the half mile run to shore. As we left the *Black Mallard* anchored in three feet of water, the bottom gradually shoaled; two feet, one foot, six inches—finally the soft mud slowed us down, and we waded ashore onto a little sandy beach bordered by a wilderness of eight-foot marsh grass. The first foot that touched a bush aroused a hive of mosquitoes so hungry and fearless that half our time was spent in a losing battle with the pests.

Two of the boys quickly laid out the little collecting seine and hauled it

ashore, spreading out the glittering dancing catch on the webbing along the beach. Then all hands began the task of collecting a definite sample of the catch which, besides thousands of tiny fish, contained the wriggling shrimp.

When hatched, shrimp are very different in appearance from their parents. They are very minute, about 1/100 of an inch long, not unlike a water-flea in form. They soon develop an elongate shape with large head and eyes and a diminutive tail, whereas in the adult the head and thorax region is about equal in size to the large tail, which contains the muscular edible portion of the animal. As they grow, the larvae shed their skins, assuming a somewhat different form with each molt, passing through seven or eight distinct stages before attaining a form similar in external appearance to the adult although less than $\frac{1}{2}$ inch long. At this size, however, the little shrimps are readily confused with other similar species that do not grow to large size and have no commercial value. It is this fact, doubtless, that leads fishermen to report a vast supply of young shrimp far offshore in deep water, for every coral head teems with a multitude of shrimp-like forms. The commercial species of shrimp, however, are seldom found ten miles from shore or in deep water; they are essentially coastal, brackish water forms feeding near the mouths of rivers on detritus from the outwash of the land.

Although it is fairly well established that the eggs of the shrimp, fertilized as they are laid, are cast free in the waters of the Gulf or ocean to develop and hatch, a mystery here develops that our investigators have not yet solved. The young post-larval stages, $\frac{1}{4}$ inch or more in length, are found both near the sea and far up in the streams and lakes that are nearly fresh, containing one half to two parts of salt per thousand. For example, here on the shores of Little Lake, thirty miles or more from Grand Pass, our seines repeatedly take thousands of these fragile little creatures. What instinct guides them and what force propels them in making such a journey from salt to fresh water? We must assume that such a journey is

SEINING FOR LARVAL SHRIMP

ON THE SHORES OF LITTLE LAKE MANY MILES FROM THEIR ORIGIN IN THE GULF.

LAYING OUT A SEINE

A THREE QUARTER MILE LONG SEINE IS LAID OUT IN THE SHALLOW WATERS OF BARATARIA BAY NEAR MANILA VILLAGE. IN LOUISIANA THE SEINE IS STILL AN IMPORTANT METHOD OF CATCHING SHRIMP.

made and that it is the result of some unknown and possibly innate force, for there is no tidal flow sufficient to explain a simple drift against the normal outflow of land drainage. But nature is full of such mysteries, resulting, perhaps, from faulty observation of her ways or faulty interpretation of scanty data. Thus is the naturalist ever lured into the unknown.

Originally shrimp fishing was carried on with seines and cast nets, but the otter trawl has now generally replaced the older methods, except in Louisiana, where huge seines twelve hundred yards long still account for a considerable portion of the catch. Following their introduction in 1916 or 1917 the otter trawl has become so popular that there were nearly 2,400 in operation in the southern states in 1929.

In addition to being sold fresh in local markets, shrimp are cooked and peeled for shipment and packed in iced cans for more distant markets as "fresh cooked." By far the greater amount, however, is canned either in tins or glass jars for domestic consumption in the

TWO SHRIMP SEINES IN OPERATION

THE OUTER ONE IS READILY DISTINGUISHABLE, MARKED BY THE CENTER FLOAT AND THE HEAD OF THE FISHERMAN STANDING NECK DEEP TREADING THE FOOT LINE. THE INNER SEINE MAY BE LOCATED ONLY BY THE CENTER FLOAT NEARER SHORE.

A BLACK-TIPPED SHARK

THE WASTE FISH THROWN OVERBOARD FROM THE SHRIMP HAULS ATTRACT MANY SHARKS, ESPECIALLY IN THE OUTSIDE WATERS OF THE GULF. IT TOOK BUT A MOMENT OR TWO TO CATCH THIS SMALL SPECIMEN OF THE BLACK-TIPPED SHARK, AND PROVIDED A LIVELY DIVERSION.

United States or dried for export to the Orient. During 1929 government records show that 767,852 standard cases of tinned shrimp were produced in the South worth $4,417,970. Of this amount nearly two thirds were of the wet pack, *i.e.*, packed in a salt brine, and one third was dry packed. More than fifty thousand cases of fancy large shrimp were packed in glass jars worth another half million dollars. These are the salad shrimp *par excellence*, and a tastier, more wholesome or nutritious bit of sea food is hard to find, unless it be in the better grades of shrimp packed in tins. Appearance of the product is the chief difference, but it accounts for a considerably higher retail price.

The canning process is a simple but highly effective one, repeating on a large scale the same type of preparation that would be practised in one's own kitchen. The shrimp are headed, washed, boiled in salt brine, cooled, peeled of the horny shell, graded according to size, placed in cans, sealed and sterilized. In one modern cannery in Louisiana I saw almost the entire process, except the heading and packing in cans, performed by machinery. No machine, however, can replace hand labor in removing the heads of the shrimp without robbing the industry of a bit of unique color. In one large room, I saw four hundred laughing, singing, colored folk, boys and girls, young and old, working at long tables performing this process. They get ten cents a gallon for the headed shrimp and a skilful worker can make $3.50 to $4.00 a day. But who wants to work that hard? Since the job is piece work, one can have a better time earning less!

Before 1890, shrimp were dried in Louisiana by Chinese and Philippinos for export to their home countries, and the height of this early development is reflected in the name, Manila Village, where shrimp drying is still carried on. After cooking in brine the catch is spread out on huge wooden platforms to dry in the sun during the day and heaped under tarpaulins at night or in rainy weather. In the old days, the shells and heads were removed from the dried meats by treading with the feet. This "shrimp step" is a strange shuffling dance that has never become popular. Nowadays, the dried shrimp are tumbled in a perforated iron box and then screened to remove the shells. Nearly two and three quarter million pounds of dried shrimp were produced in the United States during 1930, yielding an income to the producer of $1,052,883.

The waste from canning is manufactured into a shrimp meal, used as stock feed, especially valuable for poultry because of its high mineral content, and into fertilizer. During 1930, 2,402 tons, valued at $69,345, were produced, but

this yield doubtless could be greatly increased.

All told, manufactured primary shrimp products and by-products netted producers $6,082,770. This is truly an important industry, and one worthy of development and perpetuation.

Carried on for half a century and locally appreciated, the shrimp fishery arose to the level of a great industry, providing an important food commodity following the introduction of the otter trawl. In recent years production has mounted by leaps and bounds, doubling itself about every eight and one half years until in 1931 a decline in landings began. Obviously such a rate of increase can not continue indefinitely, even though markets be available, for no animal can withstand such drain upon its numbers without impairment of the supply. Nature is bounteous but not boundless. It was feared that the limit of productiveness would soon be reached and that depletion of the natural supply would result in disaster to the industry, destroying the large investment of capital and depriving thousands of dependent workers of their livelihood.

As guardians of its natural resources, Louisiana took steps to forestall calamity by regulating the fishery industry and, in order to provide wise and effective laws allowing full utilization of the natural wealth at the same time insuring perpetuation of the supply, undertook a scientific study of the natural history of the important species. The U. S. Bureau of Fisheries had already undertaken an extensive study of the shrimp throughout its commercial range, and forces were joined with the state authorities in Georgia, Louisiana and Texas to make the work more effective. Dr. Frank W. Weymouth, a well-known scientist of Stanford University, who was already acquainted with the many species of shrimp on the Pacific Coast, was placed in charge of the bureau's research staff of six, including Dr. J. S. Gutsell in North Carolina, W. W. Anderson in Georgia, Milton J. Lindner and Gordon Gunter in Louisiana, and Kenneth H. Mosher in Texas. Louisiana's research staff, under Colonel H. B. Myers, include J. Nelson Gowanloch and Forrest Durand. The Bureau of Fisheries assigned Launch 38 for work in Georgia and the motor vessel *Black Mallard*, which has been rebuilt and admirably fitted out by the state, was detailed for research in Louisiana waters.

The annual life cycle of the shrimp is a fact of utmost importance from the standpoint of conservation. In the late summer and fall, when the bulk of the season's catch is taken, the main body of the shrimp population is composed of

LARVAL SHRIMP

MIXED WITH SMALL FISH THE CATCH OF MINUTE LARVAL SHRIMP IN THE SILK-LINED SEINE WILL PROVIDE MANY HOURS OF WORK FOR WEYMOUTH AND LINDNER IN THEIR STUDY OF THE DEVELOPMENT AND EARLY LIFE HISTORY OF THE SPECIES.

LANDING SHRIMP AT A DRYING PLATFORM IN BAYOU RIGAULT

CRAFT OF ALL DEGREES OF SEAWORTHINESS ARE EMPLOYED IN THE SHRIMP FISHERY, BUT ALL ARE ALIKE IN THE CANVAS AWNING FOR PROTECTION AGAINST THE SUN.

ACRES OF SHRIMP ON A DRYING PLATFORM, BARATARIA BAY

AFTER BOILING IN SALT WATER, THEY ARE SPREAD OUT TO DRY. IN THE BACKGROUND THEY ARE BEING SHOVELED INTO BASKETS TO BE CARRIED TO THE HULLING SHED, WHERE THEY ARE TUMBLED IN A ROTATING METAL BOX PERFORATED WITH HOLES TO REMOVE THE SHELLS.

immature growing individuals that were hatched in the spring. None of them has yet spawned. Hence, if the fishery becomes so intense as to seriously reduce the stock at this time, there will be but few to survive the dangers of the winter to spawn in the spring. Certainly, the wholesale destruction of young shrimp early in the fall before they have grown to commercial size is a useless and inexcusable waste. At this time the shrimp will double in weight in three weeks and a short delay in opening the fishing season in the bays where young abound would work but little hardship. "Jumbo" shrimp are most commonly taken in March, April, May and June. Indeed, the young are just being spawned and there are no other sizes available. But the fishery, which reaches a secondary peak of production at this time, draws entirely upon the spawning population just prior to shedding the eggs. If this stock be too severely reduced there will be insufficient eggs laid to replenish the species and maintain the commercial supply. Since it appears that there is no second spawning it is imperative to save an adequate spawning reserve each year to secure the following year's crop.

How this may best be done is still a matter of experiment. No method can *à priori* be prescribed with confidence; the effects of the present spring and summer closed seasons in Louisiana must carefully be observed through the medium of the detailed statistics now provided by law. If changed regulations are desirable the biological facts now being laboriously amassed will be a reliable guide to effective and real conservation without which state, industry and public must continue to muddle through, depending on opinion, chance or whimsy.

THE PLANT COMMUNITIES OF THE DUNES

By Professor GEORGE D. FULLER

UNIVERSITY OF CHICAGO

MAN has always been interested in new things and in how these new things operate. The boy with a new watch wants to know what makes the hands go around, and he takes it apart to see how it is made and how it works. The student of nature is like the boy with the watch. He wants to know how the world came into being. He would like to have a new earth and watch it to see how the plants come in upon it, how the vegetation develops. Such an opportunity has been given on the shores of Lake Michigan, where for centuries new land has been continually in process of formation and new plant communities have been developing.

Many centuries ago a great ice sheet covered the northern portion of this continent to a depth of hundreds, perhaps thousands, of feet. The land was blotted out and all vegetation had disappeared. Some twenty thousand years ago this ice sheet melted and retreated northward from the United States. It left in its wake heaps of clay, piles of boulders, plains of sand, and pools of water. One of the largest of these pools has been named Lake Chicago, and after many changes has come to be the Lake Michigan of to-day.

The winds and the waves began their work on the shores of the lake as soon as the ice sheet had melted and the waters were clear of icebergs. The capes and headlands were first attacked by the force of the waves and were gradually washed away. The bays and inlets were slowly filled up. Some of the material removed by the waves soon sank to the bottom of the lake, but some of it traveled far and was then thrown upon the shore miles away. Because of the west and northwest winds, currents developed in the waters of the lake and the south and east shores received tons upon tons of sand thrown upon the beach by the force of the waves and piled up into

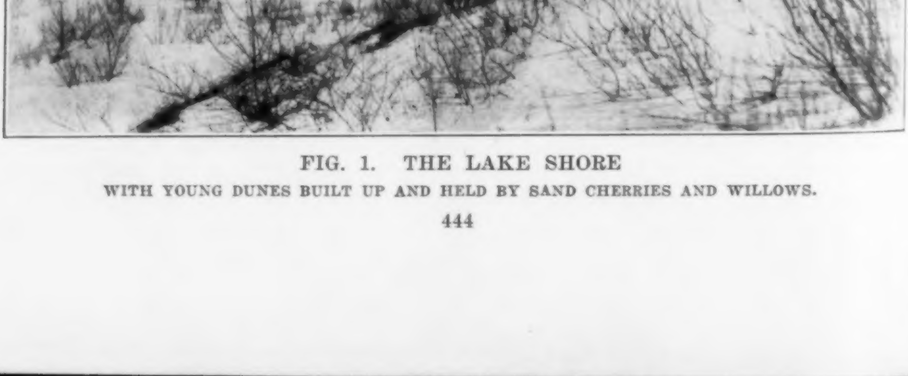


FIG. 1. THE LAKE SHORE

WITH YOUNG DUNES BUILT UP AND HELD BY SAND CHERRIES AND WILLOWS.

sand-bars. When it dried the winds caught the sand from the beach, and carrying it away from the lake, piled it into small and large dunes. Century after century this went on until the new earth measured many square miles spread out as a crescent about the southern end of the lake.

The fascinating thing about this crescent is that while the outer edge is twenty thousand years old, the inner side was built up yesterday and is receiving further additions to-day. This permits the visitor to see new sand heaped up during the past few centuries or decades with its new communities of plants, the older dunes composed of sand maturing into soil with their older vegetation, and the oldest dunes with mature soil covered with the oldest vegetation, forming a climax forest upon climax soil.

When the sand first emerges from the waters of the lake it forms sloping beaches. The surface layers soon dry out and the sand is caught up by the wind and blown landward. It is uniform throughout and moves readily in the wind until it meets some obstacle like a bit of driftwood or a clump of grass. It then piles up into an embryonic dune that in turn acts as an obstruction to free sand movement and so the dune increases in size. During the day the surface of the sand is warm; in fact, in summer sunshine it becomes hot, the temperature rising at times to 120° or more. It cools rapidly at night until it is cooler than the air. These changes and the instability of the growing dunes create conditions which few plants can withstand in spite of the good water supply that is found a few inches below the surface.

Upon the beach a few scattered annuals grow during the favorable weeks of the summer. Upon the young dunes, however, a few seedlings manage to survive, and the first permanent plants are perennial grasses and shrubs. Among the most successful are the marram grass (*Ammophila arenaria*), the sand cherry (*Prunus pumila*) and two or three low willows. The marram grass has tough rootstocks with sharp pointed ends that make their way through the sand and are constantly invading new areas. These rootstocks are often ten to twenty feet long, and together they

FIG. 2. YOUNG DUNES ALONG THE SHORE

SUCCEEDED BY A PANNE WITH COTTONWOOD SEEDLINGS FOLLOWED BY COTTONWOOD DUNES IN THE RIGHT BACKGROUND.

FIG. 3. A PINE ASSOCIATION
DEVELOPED ON DUNES SHELTERED BY THE COTTONWOOD DUNES SEEN IN THE BACKGROUND.

form a network that tends to hold the sand in place. The sand cherries and willows are easily able to survive burial by sand as the dunes increase in size. One shrub thus becomes several, for each stem or twig covered sends out new roots and may soon become independent of the parent plant. Shoots, too, come up from the roots and assist in spreading the shrubs. This grass-cherry-willow association sparsely spread over the young growing dunes is the pioneer plant community (Fig. 1).

In depressions that are caused by wind sweeps between the young dunes or that have come from the filling up of lagoons surrounded by sand-bars, the sands are constantly damp, at least they are damp when the seeds of the cottonwood (*Populus deltoides*) are ripened in June. These downy seeds are short-lived but easily carried by the wind, and when they fall upon the damp sand they germinate within twenty-four hours. Thousands of these seedlings may be found every summer in these "pannes," as the damp depressions in the dunes are called (Fig. 2). Most of these die during the scorching heat of July and August and others succumb to the gales and frosts of autumn and winter, but here and there a clump survives and lays the foundation of a cottonwood dune.

These clumps of young cottonwoods form a living obstacle to the moving sand, and growing dunes are formed. These dunes are larger than those with grasses and shrubs, as trees grow taller. The cottonwood trees, however, are like the sand cherries and willows in sending out roots from trunks and stems that are buried and in sending up shoots from roots that are near the surface. Such spreading and multiplying trees, together with the willows and some of the grasses of the pioneer plant community, constitute the second plant community upon the young sands—the cottonwood

dune association (Figs. 2 and 3). This is an open community, the plants covering less than half the surface of the dune.

This openness and the greater size of the dunes results in instability and many of the cottonwood dunes are constantly moving away from the lake. As the new dunes appear the older ones get to be farther and farther from the lake. The younger dunes afford the older ones some shelter and more plants come in. There are the low junipers (*Juniperus communis*), the Jack pines (*Pinus banksiana*) with bunch grasses (*Andropogon scoparius*) and a carpet of bearberries (*Arctostaphylos uva-ursi*) with wintergreens (*Pyrola* and *Gaultheria*) twin flowers and many other northern plants (Fig. 3). The red cedar (*Juniperus virginiana*) and the white pine (*Pinus strobus*) soon join the community and a score of shrubs and herbs appear. They stand so closely together that they really form a forest and soon crowd out the earlier pioneer plants. The surface is well shaded, the sand can no longer move, and changes begin in it that are transforming the sand into soil.

As rain falls and snow melts the water passes down through the sand, removing certain minerals from the upper layers and carrying them down into the layers beneath. The pine needles and other leaves that fall to the ground lie there until they decay into humus that mingles with the upper layers of the sand. Dying roots also add their quota to the humus. The results are that the surface layers become darker in color, will hold more moisture and have a somewhat acid reaction. The water and

FIG. 4. AN OLDER DUNE

WHERE THE OAKS ARE INVADING THE PINES. A RAPIDLY ADVANCING DUNE IS SHOWN AT THE RIGHT.

FIG. 5. A BLACK OAK FOREST ON A LEVEL BIT OF DUNE SAND.

the vegetation are changing the sand into soil and making it ready for plants of a different sort.

In the shade of their parent trees pine seedlings do not thrive. But scattered through the pine association are oak seedlings that grow the more vigorously because of the shade afforded by the pines. Hence in the competition which follows, the oaks gradually replace the pines (Fig. 4), and on dunes a few thousand years old there is a forest of black oak (*Quercus velutina*) with a few scattered pines remaining and a few white oaks, sassafras and basswoods (*Tilia americana*) coming in (Fig. 5).

The oak forest requires more water than did the pines, hence the trees are not very large and they stand far enough apart to permit a great variety of shrubs and herbaceous plants to cover the forest floor. There are the dwarf and the aromatic sumach (*Rhus copallina* and *R. canadensis*), the maple-leaved viburnum and the bush honeysuckle (*Diervilla lonicera*), the choke cherry and the New Jersey tea (*Ceanothus americana*); while on the more sheltered slopes witch hazel (*Hamamelis virginiana*) and flowering dogwood are growing. Blueberries and huckleberries show that the soil is now acid.

There are few spring flowers in these oak dunes, but from late spring to the autumn frosts there is a succession of bloom that is unsurpassed. Before the end of May the sand violets (*Viola pedata*) are in bloom. They are followed by showy blue lupines (*Lupinus perennis*) and the delicately tinted hoary pea (*Tephrosia virginiana*), the pink wild roses (*Rosa blanda*), and the white phlox (*Phlox bifida*). Then come the yellows of the cactus (*Opuntia rafinesquii*), the frost weed (*Helianthemum canadense*), the puccoon (*Lithospermum gmelini*), the coreopsis (*Coreopsis lanceolata*), and the false foxglove (*Gerardia pedicularia*) passing into the orange of the butterfly weed (*Asclepias*

tuberosa). By midsummer the sunflowers, the black-eyed Susans (*Rudbeckia hirta*) and the wild bergamont (*Monarda punctata*) begin to bloom and are followed by blazing stars (*Liatris*), asters and goldenrods, while blue gentians and witch hazels are in flower when frost comes.

Soil changes now go on slowly, but more humus is gradually being incorporated into the surface sand and the humus from the oak leaves is less acid than that from the pine needles. The clovers and their relatives have also been increasing the nitrogen content of the soil, in a word, the soil is becoming gradually better and better.

The black oak association endures for centuries with little change, but gradually the better soil produces a better forest. White oaks and red oaks (*Quercus borealis*) gradually replace the black, and other trees such as basswood and maple (*Acer saccharum*) become more numerous. The trees are now larger, they grow more rapidly and form denser shade (Fig. 6). As a result, many of the summer blooming plants that were found in the black oak forest disappear from the red oak-white oak forest. The shade plants survive and the sun plants disappear. This forest community is really mesophytic.

Changes continue until on the oldest dunes, that are perhaps more than fifteen thousand years old, the richest of plant communities—the beech-maple-hemlock forest—becomes established. This forest is dense and the shade is deep; only trees that tolerate deep shade can grow in it. These trees are the sugar maple, the beech (*Fagus grandifolia*), and the hemlock (*Tsuga canadensis*), a few basswood and tulip trees

FIG. 6. RED AND WHITE OAKS

WITH AN UNDERGROWTH OF SUGAR MAPLE SEEDLINGS; A FOREST THAT IS ALMOST A CLIMAX.

FIG. 7. A CLIMAX FOREST OF MAPLE, BEECH AND HEMLOCK ON AN OLD DUNE.

(*Liriodendron tulipifera*) and some remnants of the former forest such as an occasional red or white oak (Fig. 7). The other trees and shrubs of the oak forests have disappeared, having lost out in the competition with the beech and maple trees.

This forest is regarded as a climax, because it is the end member of a series of forests that have lived, died and decayed to make the climax possible. Then, too, it is the richest of all the forests in the region and it is able to reproduce itself indefinitely—it is a permanent climax.

Within this forest shrubs are few, and they are quite different from those found with the black oaks. There is an occasional red-berried elder (*Sambucus racemosa*) or a bush of the tough-barked leatherwood (*Dirca palustris*), and some of the dune slopes are thickly carpeted with the ground hemlock or yew (*Taxus canadensis*).

The shade is so dense that most of the summer flowers have disappeared. The sand violets, the cacti, the lupines, the butterfly weed and the sunflowers have all gone. Instead, there have come in a host of delicate spring flowers and a few shade plants that bloom in the early summer. Early in the spring flowers of the hepatica and bloodroot open and are soon followed by squirrel's corn, Dutchman's breeches and miterwort (*Mitella diphylla*); a little later there are long-spurred, white and yellow violets, golden bellworts (*Uvularia grandiflora*) and celandine poppies (*Stylophorum diphyllum*), white rue anemones (*Anemonella thalictroides*) and splendid masses of great white trilliums (*Trillium grandiflorum*). They are followed in the early summer by the white flowers of the sweet cicely and baneberry (*Actaea alba*), while there are columbines (*Aquilegia canadensis*) on slopes that get more sunlight. Ferns, too, have appeared.

There are marginal shield ferns (*Aspidium marginale*) and Christmas ferns (*Polystichum acrostichoides*) scattered throughout the woods, while the delicate maiden hair (*Adiantum pedatum*) and the golden spleenwort (*Asplenium acrostichoides*) are found in the more sheltered spots. These are only the more common plants; others quite as beautiful may be found by the careful observer.

This richness and luxuriance in the plant community indicates a corresponding richness of soil quite different from the bare sand of the youngest dunes. Digging down there is seen a mature soil profile of three distinct horizons. First, underneath the dead leaves there are several inches almost black with the humus and leaf mould; then a thick layer of gray sand with particles of a mould and with some minerals leached from the soil above; while below comes the dune sand itself practically unchanged throughout the score of centuries that have passed since it was first cast up by the waters of the lake.

Thus within this crescent of dunes forty miles long and five miles wide is condensed the history of twenty thousand years of plant development. Within the limits of a half day's walk one may read a summary of the succession of the plant communities that have developed throughout the period, a succession extending from pioneers on the new wave-washed, wind-blown beach sand through the shifting sands of moving dunes to older and older areas of fixed sand hills with better and better soil, producing succeeding generations of plant communities of ever-increasing richness, culminating in a permanent climax forest on climax soil twenty thousand years old. There is no better place for the plant scientist to see how new land is formed and how it becomes mature soil with its succession of vegetation.

SOMETHING ABOUT THE EARLY HISTORY OF THE MICROSCOPE

By GUSTAVE FASSIN

INSTRUCTOR IN MECHANICAL DESIGN OF OPTICAL INSTRUMENTS,
UNIVERSITY OF ROCHESTER

On the milestones to civilization we find the names engraved of the men who have devoted their lives to the benefit of mankind. Let us dream back for a few minutes and pay tribute to the pioneers who laid the foundation stones for this temple of science which we are building.

THE specially-shaped transparent materials mentioned in some of our books dealing with the most primitive civilization are thought by modern writers to be lenses. For example, the elliptical quartz object which Layard found in the ruins of Nineveh was regarded by Sir David Brewster as a lens, and "Three Crystal Magnifying Lenses of Modern Form" (small discs with one convex side) found in the Minoan tombs at Knossos in Crete, are reported by the British School of Athens (session 1926–27) (Fig. 1).

In the classic literature of the ancients we find several chapters where lenses or mirrors are mentioned—Pliny tells us how Nero, being myopic, looked through a concave emerald to watch the gladiatorial combats. Seneca describes the magnifying power of glass globes filled with water. Burning-glasses, says Pliny, which were composed of glass balls filled with water were used by physicians to cauterize the flesh of patients. In "The Clouds," Aristophanes (B. C. 423) explained that the druggists of Athens sold transparent stones for kindling fire or melting wax by solar rays. Here, however, there is no clue to their shape or origin.

The first more or less scientific description of the magnifying power of shaped glass objects (plano convex in this case) is to be found in the book of the Arabian mathematician Al Hasan, who died in Cairo in 1038. One hun-

FIG. 1. AN ASSYRIAN "LENS" (?).

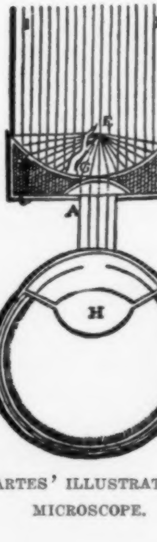


FIG. 2. DESCARTES' ILLUSTRATION OF A SIMPLE MICROSCOPE.

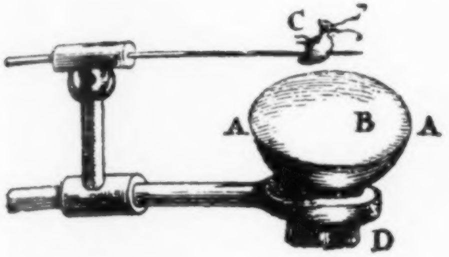


FIG. 3. LIEBERKÜHN'S MICROSCOPE (1739).

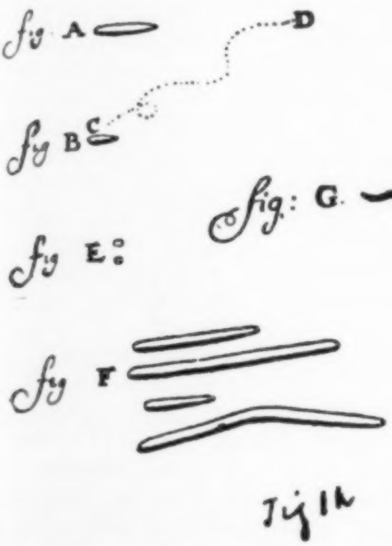


FIG. 5. VAN LEEUWENHOEK'S "LITTLE BEASTS." AS PUBLISHED IN ONE OF HIS BOOKS.

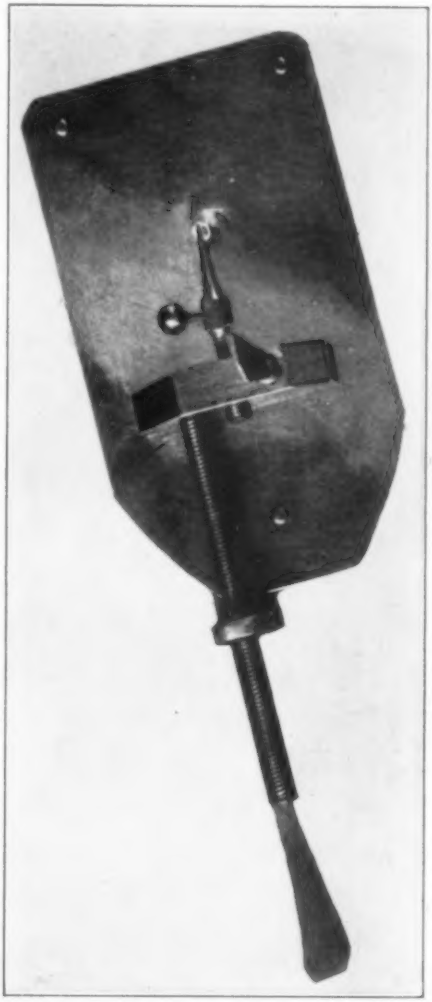
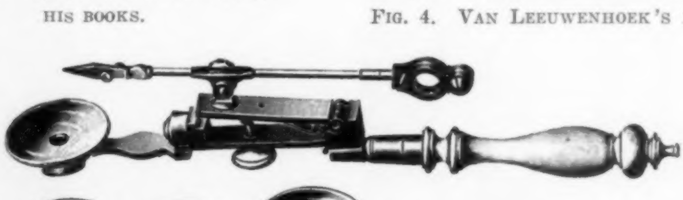


FIG. 4. VAN LEEUWENHOEK'S MICROSCOPE.



½ size.

FIG. 6. COMPASS MICROSCOPE.

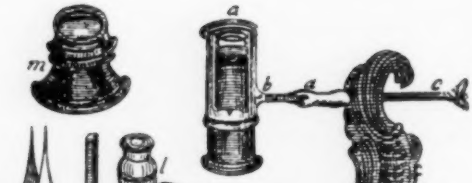


FIG. 9. WILSON'S MICROSCOPE WITH STAND.

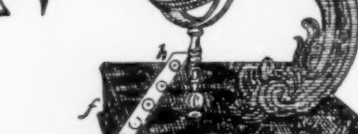


FIG. 7. CUFF OR WILSON'S POCKET MICROSCOPE.

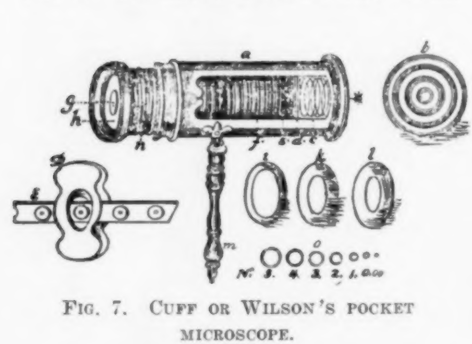


FIG. 8. LEDERMÜLLER'S MICROSCOPE ON A SIMPLE STAND MADE BY BONAMI.

dred and fifty years later Roger Bacon (1214–1292) suggested the possibility of obtaining enlarged images by looking through spherical transparent materials of suitable densities.

Although glass was known from the earliest ages, the art of finishing it was very crude. In the thirteenth century the Venetians, in their enthusiasm for the manufacturing of a highly polished mirror, were using a slow grinding process, known at that time for polishing jewels.

Once the technique of polishing became known, the manufacturing of spherical surfaces did not cause much difficulty. The first application of polished lenses was made in correcting the eye. It is very difficult to decide upon the inventor of the spectacle lens; we hesitate between Signore Salvina Armato degli Armati, of Florence, and the priest, Alexandre de Spina, but the first appearance of the spectacle may be fixed, without error, at the last quarter of the thirteenth century.

The principles of the compound microscope were worked out by Johannes and Zacharias Janssens, of Middleburg, Holland, about 1590. In 1691 Mr. Bonani published a book giving a list of investigators engaged in microscopical research work. He mentioned, in the first place, Hufnagel, of Frankfurt, who in 1592 published a book about insects, with 50 illustrations. Soon after this a series of books about microscopical research work was published, and during the Thirty Years' War the simple microscope was generally known. We read in Descartes' "Dioptric et Meteora" the description of this instrument. He calls it "perspiculia pulicaria ex uno vitro." This means "flie-glass with one lens." An illustration of this "flie-glass" occurs in his remarkable work. (See Fig. 2.)

A is a lens; this is not an ordinary

spherical lens but a convexo-hyperbolico-plano. The entire instrument is mounted in a frame C. The side of this frame, facing the light source, is a concave mirror which concentrates the light upon the small object fixed on the point of a prong E in the focus of the lens A.

This particular instrument was made for hand use, but Descartes proposed a microscope of larger size based on the same principle. Here, however, we observe the use of a condenser lens, instead of a parabolic mirror to concentrate the light on the object.

The instrument shown in Fig. 3 was specially used for the microscopical study of insects. The optical toy called the "flie-glass" was well known. When the famous priest Scheiner died, a "flie-glass" was found in his possession. His neighbors regarded the "flie," seen through the glass, as the devil and looked upon Scheiner as a magician.

The most famous of the microscopists at that time was Antonie Van Leeuwenhoek, who was born in Delft on October 24, 1632, and died there on August 26, 1723. He made his microscopical studies a hobby, polished his own lenses and made all the mechanical parts of his microscopes himself. Through the documents of his time and also through his published works we learn that his lenses were excellent and that he was a master in making microscopical preparations. In 1674 he gave the first accurate description of the red blood corpuscles and investigated the structure of the teeth, the crystalline lens of the eye and other physiological objects. In 1680 he stated that yeast consisted of minute globular particles. Fig. 4 represents a microscope as used and made by this scientist.

A small lens is fixed between two metal plates. On the one side is a specimen holder, which can be moved up and down by means of a screw. A screw for focusing was also provided. The illumination of the object was arranged, as in the Descartes' instrument. A concave mirror was fixed around the lens, but generally he worked only by transparencies. The magnification of this instrument was in some cases as high as 160X.

Van Leeuwenhoek was also the first microscopist who gave a description of bacteria. Fig 5, taken from one of his works, represents his reproduction of bacteria found in the mouth. He calls them "levende dierkens" or "living little beasts." Reports of his discoveries were sent to the newly formed Royal Society of London, and he was elected a member of the society in 1679.

FIG. 10. MICROSCOPE WITH REVOLVING NOSE PIECE MADE BY ADAMS, LONDON.

For a long time the optical perform-

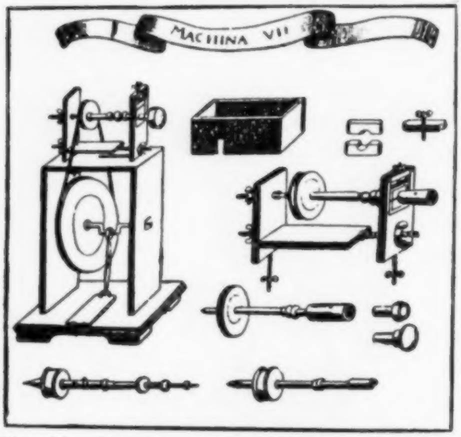


FIG. 11. OPTICAL MACHINERY AS USED IN THE EIGHTEENTH CENTURY.

ance of Van Leeuwenhoek's microscope was not improved nor even equaled, but the mechanical construction developed rapidly. Van Leeuwenhoek is a brilliant example of what a man, animated with the love of science, can produce. He was an amateur, not a professional microscopist. It is remarkable to see how he worked, basing his theory on his observations instead of on his philosophical reasoning, such as had been the usual custom before this time:

Professor T. Musschenbroek improved the mechanical part of the microscope, by making it possible to change the objective lens in the microscope for different magnifications. Van Leeuwenhoek had used a different instrument for each power. Musschenbroek built his microscope on a base so that the operator had the use of both hands. He also used the knee-joint stand for the first time to provide a comfortable observing position for the instrument.

About the same period we find the compass-microscope (Fig. 6). One leg of the compass carries the lens; the other, the object. The distance between the two elements could be adjusted by means of a screw. A Descartes' mirror was used for illumination. This, too, was a hand instrument.

A real improvement was made in the construction of the instrument by Ledermüller, who calls it a Cuff's or Wilson's pocket microscope (Figs. 7 and 8). Between an object holder A, the specimen is pressed against a diaphragm by means of a coil spring. The lens is mounted in a tube which screws in the body tube of the instrument and provides in this way an accurate focusing device. This instrument was further provided with a condenser lens and interchangeable diaphragms made out of colored parchment or thin sheets of metal.

Fig. 9 shows real progress in the mechanical construction of this instrument —the microscope is built with a stand. A mirror for illumination is provided. m,k,l,i are the different tools used by this instrument. From 1704 to 1750 a great number of instruments of this type were made with slight improvements.

The photograph, Fig. 10, is one of the first microscopes, made by Adams, of London, which was provided with a revolving nose piece with 8 lenses.

Johannes Zahn published in his "Oculus artificialis" Fig. 11, which repre-

FIG. 12. HOOKE'S COMPOUND MICROSCOPE.

FIG. 13. GRAY'S WATER DROP MICROSCOPE.

sents the machinery which was used at that time to grind and polish the lenses. The polishing of the very small lenses used in microscope objectives was a very difficult problem, and they tried in another way to obtain a usable product—namely, by melting the glass into very small balls, which on some occasions gave very good results; Professor Harting tells us that with such a lens Hartsoeker studied spermatozoa, and this work certainly needed a very high magnification. In a Dutch review "Prometheus," 1895, Professor Brunk gives a complete description of the manufacture and use of such glass ball microscopes.

The inventor of this method, Robert Hooke, published in 1665 his "Micrographia" (written in English) which contains 60 microscopical observations, made and described with the greatest accuracy. We find also a complete description of a "compound microscope" (Fig. 12). The tube length was 6 or 7 inches, but could be very much lengthened by means of several draw tubes. An object lens and two eye lenses were used; one of these lenses was a field lens and "could be eliminated to reduce the refraction, by observation of small objects." A glass ball filled with water was used as condenser.

This microscope was manufactured in 1667. Hooke, although a man with a disagreeable disposition, was a most remarkable experimentalist. His observations were made with the greatest precision and his microscopical drawings were full of details. In the description of his work he says, "Then examining it according to my usual manner by varying the degrees of light and altering its position to each kind of light. . . ."

The monk Giovani Maria dela Torre

FIG. 14. MICROSCOPE MADE BY ELLIS AND VAN CUFF.

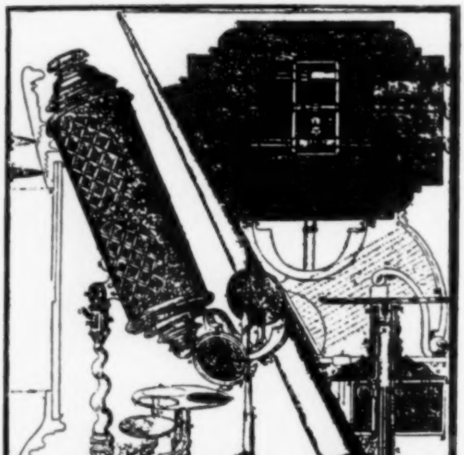


FIG. 15. MICROSCOPE MADE BY PROFESSOR HERTEL.

was famous in the manufacturing of small microscopic lenses, made by the smelting method, invented by Hooke.

A very curious instrument was made by Gray, who used a very small drop of water as objective lens. Fig. 13 represents the Gray's microscope. The opening A held the small drop of water that served as objective lens; the object was fixed on the beak F or in the opening C when infusoria were to be examined.

Griendl Van Ach was famous for his good microscopes. He assembled plano-convex lenses following a method given by the Italian Divini. The convex sides of the lenses were turned toward each other, and the whole objective was a combination of three such pairs.

About 1750 Ellis and Van Cuff manufactured a microscope with a construction comparable with the more modern microscopes. With this instrument (Fig. 14) he made a remarkable study of corals. The use of a condenser lens was well known in his time, but he was the first to build this lens into a mechanical device, so that focusing was possible. Charles Darwin, 100 years later, used a similar instrument in his research work.

A micro-focusing device or slow motion screw was suggested by Pritchard and first applied in a type of microscope made by the English manufacturer Ross.

The German Professor Hertel (1703) combined in his microscope all the perfections of the eighteenth century. In this instrument, however, the focusing device was incorporated in the stage, together with a device, similar to the modern mechanical stages, for moving the stage from left to right and back and forth. (Figs. 15, 16 and 17).

In England Marshall, Cuff, Baker and Jones now became well known for their instruments—especially Marshall, who manufactured powerful objectives and made them interchangeable.

The greatest step forward in the op-

FIG. 16. MICROSCOPE BUILT ABOUT 1700.

tics of the microscope was made through the manufacture of achromatic lenses. The first achromatic objective for telescopes was made by John Dollond (1706–1761), following the suggestion of Leonard Euler, the mathematician. Some scientists claim that credit for this is due to Chester More Hall (1722).

The first achromatic objective for the microscope was presented by the Russian state counsel Aepinus in 1784 to the Academy of Science of St. Petersburg. This instrument had an objective of 7 inches focus, and, therefore, a very low magnification. Its length of 3 feet made it very difficult to handle.

The first useful and good achromatic objective was made by the Dutch cavalry officer, Frans Beeldsnyder, in 1791. It was composed of two convex lenses of crown glass with a bi-convex lens of flint glass between them. The focal length of this lens was 21 mm and it had wonderful definition.

The first achromatic microscopes were constructed by Van Deyl and son, and Fraunhofer in München, but the magnifications were low and the competition with the simple microscope difficult. Selligue's idea of using a series of several achromatic systems was worked out by the brothers Chevalier. With the realization of this high power achromatic objective the simple microscope was superseded.

The same brothers Chevalier were the first to cement the lenses together with Canada balsam. Amici, French mathematician, improved in 1815 the objectives by turning the lenses with their plano side toward the object, so reducing the spherical aberrations of the Chevalier system in which the convex side was toward the object. Amici was also the first to use one complete objective for each magnification instead of screwing the lenses together to make more or less powerful combinations.

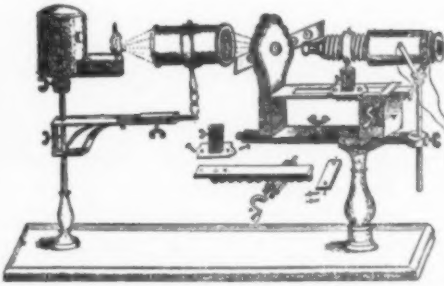


FIG. 17. MICROSCOPE WITH ILLUMINATION EQUIPMENT CONSTRUCTED IN 1691 BY BONANI.

The immersion system and the correcting of the objective for the thickness of the cover-glass were Amici's inventions.

Ross and Wenham made their objectives adjustable for different thickness of cover-glass—a technique which is still in use.

In Europe, with Zeiss, Abbe and Schott, the microscope reached its highest perfection. In the United States, Spencer and Bausch and Lomb were the pioneers in the field of microscope manufacturing, and their daily contributions toward science and industry are of inestimable value.

This brief history of the early microscopes brings us up to the closing quarter of the nineteenth century. Even then there was much left to be done. In 1870 there were only 50 microscopes in this country. In 1930 there were at least 50,000 in use.

This great development was influenced partly by the steady growth of scientific activities, but great credit must also be given to the early microscopical societies, with their large memberships of amateur microscopists. These amateurs did for the microscope what the radio amateur did for the advancement of radio. Now that science has made the instrument its own, there are few amateurs left, but microscopy still remains one of the most fascinating of pursuits.

OPTICS AND MODERN PAINTING

By Dr. ROGERS D. RUSK
DEPARTMENT OF PHYSICS, MOUNT HOLYOKE COLLEGE

THERE is perhaps no field of thought in which pseudo-scientific explanations have been more confused or more in actual error than in the optics of modern art. At the same time these declarations have been made with an air of finality and authority that could scarcely be more misleading, and they have masqueraded under an apparent profundity which at least to the layman was incontrovertible. The reason may be that the problem of the artist when stripped of its intellectual and emotional attributes is purely an optical one and yet the artist is not often a scientific expert in optics, but rather he is one who would forget science in his search for what is "not-science." In no art, however, except music is the technical basis of the art more exacting or more clearly defined than it is in painting, and as little as the artist may care to admit it, or as little as he may care to consciously cater to it, optics in one form or another is a chief essence of his object and method.

Primitive man attacked the problems of rendering form in two dimensions on the walls of his cave, and in three dimensions on his totem poles and images, but it was not till the time of Piero della Francesca in the fifteenth century that the first real conquest was made of the problem of representing three dimensions on a two-dimensional surface. One by one the various optical problems involved in painting have been thus attacked—chiaroscuro, perspective, shadows, design, and finally the problem of color, about which the Impressionist group was so greatly concerned and with regard to which there is yet so much misstatement and mistaken thought.

In the latter part of the nineteenth century the little group of Impressionists fostered by Manet and Monet introduced a new era in the use of color and light which in due time became the most important influence in modern painting. In this same century came that remarkable development of the modern theory of light in which the supremacy of the Newtonian emission theory was overthrown by Young and his followers, and the wave theory was accepted. Furthermore, the scientific principles of color relation were being formulated by Chevreul, Helmholtz, Maxwell and others, and these new discoveries opened up wide horizons and presented a statement of basic principles hitherto unrecognized. Such new levels of thought and action, whether technical or esthetic, are noteworthy for the way in which we suddenly come upon them, although the preparation may have been quietly going on for generations, and it is not surprising that a new era in art should accompany this technical revolution in so closely related a field.

There is even a deeper philosophical basis for the change in view-point. The Kantian philosophy had swayed Europe and had called attention to the difference which must exist between things-as-we-see-them and things-in-themselves. The positivist had gone much further and said that we must only talk in terms of sense-impressions. Ruskin and even Chevreul had applied the term "impression" in art, and Manet in 1867 had staunchly asserted the right of a painter to render his own personal impression. When, along with others, Monet used this term in the title of his picture

"Impression, soleil levant" in the exhibition of 1874 it became fixed upon the group as a name to signify the new movement, in spite of Monet's own objection to being tagged by it. It is not the name Impressionism with its many connotations which is important but rather the movement toward a full knowledge and a bold use of the newly discovered color relations, for which also the not altogether satisfying terms luminism, chromatism, divisionism and even "chromoluminaristes" have been suggested. After all it is perhaps best not to try and displace a term so generally accepted and which carries with it an emphasis on more than the merely technical phase of the movement.

Without the name, and without even the group, the revolution in painting would have come sooner or later under some name and with some group because the way had been paved by the necessary advance in optics. Whether or not we have passed beyond the immediate circle of influence of Impressionism or Post-impressionism is likewise unimportant, for no matter which way the pendulum swings to-day the influence of the new optics of light and color is unmistakable and lasting. It furnishes a powerful technique for the artist to use as consciously as he pleases. It reveals to us the world of color in which we live, and furthermore it parallels the interest of the scientific world in the light which furnishes our world with life and color and which purveys to us most of our knowledge of the universe from stars to atoms.

No artistic movement in modern times ever suffered more resistance nor were its adherents held up to more public calumny and actual shame than those who were officially barred from the Salon of 1863, who first exhibited as a group in 1874, and who received little or no encouragement till the eighties. However, the movement toward a liberation of our ideas of color and light, both technical and esthetic, is as real to-day as when it was first conceived and now, nearly sixty years since the group received its name, it is more than time that the commoner misconceptions of the optics of the movement be cast aside.

It has been said that Monet was "a great eye" (even Cezanne was heard to murmur it), but that is scarcely an adequate optical explanation of his art, for likewise he was a great hand and, because by his own admission he only painted his pictures as far as his vision would allow him, his hand was as great or greater than his eye. No doubt the central nervous system should also receive its share of credit—as even a behaviorist would have to admit. A leading biographer[1] of Monet enthusiastically declares that he possessed a spectroscopic eye, which led him to paint pictures that were "perfect demonstrations of the theory of atomic dissociation." This statement can be taken as hardly more than pseudo-science at its worst. Unfortunately for the figure of the great eye, which is pleasant enough in itself, the ability of an artist can not be localized in one member and indeed every real artist must have a "great eye."

A statement as definitely at odds with common optical principles as that of the "spectroscopic eye" is the statement attributed to Sargent, who thought the colors were produced on Monet's retina by his astigmatism. However, the most prominent effect of astigmatism is the well-known blur of lines in one direction with sharp focus of lines at right angles, and headaches rather than color effects are the prevailing results of such trouble, as plenty of astigmatics will testify. Color effects, if they did exist, would probably provide surprising colored borders to objects, and in no way the effects

[1] Camille Mauclair, "Claude Monet," p. 29.

reported on canvas by Monet. It is true that Monet suffered from eye weakness, and long exposure to bright sunlight may very well have hastened his failing sight, but the Impressionist movement can hardly be attributed to this, and rather it must be thought that Monet achieved his results in spite of weakness of vision.

A more obvious effect of astigmatism is the lengthening or shortening of an image, and this has been often invoked to explain the elongated images of El Greco. Indeed by holding a correcting astigmat lens before an El Greco figure it shrinks to very much its natural proportion. Unfortunately for this theory, however, El Greco's earlier pictures were in normal proportion, and the distortions suddenly came to him on his visit to Toledo from Italy. Now it is a well-known fact that astigmatism is a very slowly progressing defect, if it progresses at all, and by no means does it attack one with such furious suddenness. Furthermore, and most unfortunate of all for the theory, El Greco painted at least one picture, "The Burial of the Count of Orgaz," in which appear both distorted and undistorted pictures at the same time. We are left to fall back on the not unsatisfying conclusion that El Greco knew very well all the time the effects he desired and the means he proposed to use to gain those effects.

It is in the subject of color theory, however, where the most egregious blunders are committed, and these are the more to be regretted because of the many who have pretended to write on the subject of color under the cloak of more or less technical authority. There may be some excuse for certain lesser blunders in the fact that even to-day artists and scientists in optics may haggle over the use of terms in spite of committees that have been appointed to iron out their differences. There is no excuse, however, for such an error, a common one it must regretfully be admitted, as occurs in a standard book on modern French painting.[2] It is stated in illustration of the blending of closely juxtaposed spectral hues that a more brilliant green is to be obtained not by mixing pigments representing the adjacent hues of yellow and blue, but by the light from the closely juxtaposed pigments mixing or blending in the eye. Unfortunately, yellow and blue are the only two colors in the spectrum which when blended in the eye will not produce the color located between them, but quite on the contrary in the proper proportion they will give a white considerably reduced in brightness.

This goes back to the whole misconception of color of Sir David Brewster and others, which Sir David had expounded not wisely but too well about the middle of the century and which was called severely into question by Helmholtz in 1852. Indeed, it was this very fact, that green is the one color which can not be produced by blending other colors in the eye, which had led Young at the very beginning of the century to assign green as one of the three primary sensations of the retina. This assignment later disputes have failed to displace, but it had to be rediscovered by Helmholtz in Young's earlier papers. Then once and for all became crystallized the famous distinction between the "red, green, and violet" primaries necessary to explain the additive effects of colors blending on the retina, and the "red, yellow, and blue" primaries, which had long been used to explain the subtractive effects of mixing pigments. The difference between mixing pigments and mixing colored lights in the eye was a long time being straightened out, but straightened out it has now been for

[2] Jan Gordon, "Modern French Painters," p. 22, 1923.

many a day and there is not the slightest excuse for such errors being perpetuated either by art critics or by pseudo-scientists. Indeed from the notes of Leonardo himself it appears that even he had recognized the uniqueness of the green.

But what of the other colors which may legitimately blend to produce that color located in the spectrum between them? A second fallacy now appears because of the simple fact that there is not anywhere near complete blending of the colors in the eye as there may be in nature itself unless the spots are absurdly small or the distance of the observer absurdly large. A simple experiment will show this, and it is usually a surprise to the experimenter to observe how far away quite small spots of juxtaposed color of different hues can still be observed as separate spots. One can appreciate this by backing away from a picture done even as delicately and minutely as Seurat's "La Grande Jatte." It was to get around this difficulty that the later exponents of so-called pointillism experimented with smaller and smaller spots, only to find that as the spots became smaller and smaller the time necessary to apply them became longer and longer, and the mosaic produced was less painting in the ordinary sense and more and more a craft.

From the view-point of optics a good way to aid the juxtaposed colors in blending together would be to produce a slight rapid motion of the object so that the retinal images continually overlap or are successively superposed as may be easily shown by experiment. To pursue this suggestion to its unhappy logical conclusion, it might seem best to hang Impressionist pictures from a kind of electric vibrator. However, one can scarcely imagine the justifiable amazement and indignation of the esthete on entering a gallery and beholding favorite copies of revered masters executing an indescribable jiggling tango upon the walls of the museum, while more staid and classic ancestors looked on from other walls in calm rebuke. Very obviously it is not so much the blending of the colors as their relative contrast which is essential. Some critics rather picturesquely call it the *collision* of the colors, others call it the vibration of the colors, which is rather unfortunate, as the actual vibration of a light wave is something entirely different and amounts to hundreds of trillions per second, being of course wholly unperceived by the eye. It is this contrast or collision which reproduces the dazzling brightness or the softer shimmer of sunlight. When the critics speak of the greater brilliance so obtained the term must not be interpreted as measuring brightness, in the physical sense, because the eye may not receive appreciably more light from the area covered by two closely juxtaposed hues than if the mixed pigment were spread uniformly over both areas. That is a matter which involves the question of reflection coefficients and the chemical and physical effects of mixing pigments. If the term brilliance be so used as to imply contrast effects and not mere brightness the fact must be recognized. Some word indeed is needed to convey this idea, which is a chief element in the optics of Impressionism.

We see then that Impressionism brought with it an enlarged recognition and use of the principles of color contrast, and the distinction between the problems of the additive color combinations on the retina and the subtractive color combinations of mixed pigments. The major credit for formulating the first statement of the principles of color contrast must be awarded to Chevreul, the chemist, in spite of the fact that he labored under some of the current misconceptions. Chevreul turned his atten-

tion to colors in the interest of the Gobelin tapestries and published his significant treatise on the laws of simultaneous color contrast in 1839. The problem presented to Chevreul was simply why does black cloth sometimes seem black, sometimes seem a rusty brown or sometimes a deep blue? Surely a chemist of such fame should be able to tell if the dyes are at fault, and if the customers who have complained have the right to financial redress. To answer such a question the chemist proved his ability by turning physicist, and in the end enunciating laws more fundamentally psychological than anything else. The problem, however, was not new. The artist of to-day speaks of a color as "telling" differently on the picture than alone on the palette, and in the early days of painting with limited colors this fact was fundamentally important. A gray in the eyes often would "tell" as a blue. Such deception through contrast was well known, but its laws were not known until the work of Chevreul by whom they were first set down in logical form.

Chevreul also saw that the so-called local color of an object might be one thing, but its appearance under different illuminants was something else. The surface atoms of a substance not only may not tell us of the underlying reality, but they tell a different story under different kinds of illumination. To-day we know that when a surface appears blue it may actually be reflecting quite a range of wave-lengths, and blue may simply be the predominating effect which has been registered by the eye. It is the old story of the difference between the Kantian phenomena and noumena, and through it we are led to the positivistic view that for us as observers the sense impressions are the important things. Chevreul showed that these sense impressions are relative, and so as Einstein put relativity into the world of space and time, so also did Chevreul put relativity into the world of color.

The first step in the rediscovery of reality through the medium of color and light was the return of the naïve recognition that green leaves might be painted green, and later came the climactic discovery both in optics and by the artists themselves that green leaves might be painted orange, blue, violet or any other color, depending on a variety of controlling factors. Later in the century Rood was to publish in his book a chart showing that green leaves actually reflect, in addition to some white light, not only green but also strong yellow and red. These ordinarily blend on the retina to give a yellowish green, but when such leaves are viewed in the light of an intense blue sky they may reflect a much bluer green, or in the light of the setting sun more nearly a red or orange.

Delacroix was the first of the moderns to rediscover the world of color—see, for example, his Massacre of Scio done in 1824—and his biographers assert that his interest was so great when the theories of Chevreul were later published that he studiously constructed charts of his own and made an attempt to see Chevreul in person, which was only frustrated by illness. The world of art owes much to Delacroix, but it was Manet years later who was always recognized as the leader of the group that met so regularly on those Friday evenings at the Café Guerbois and who put the new movement on its feet. According to Duret it was Manet who gave Monet the inspiration which led to the movement as we now know it. Manet's genius had led him to a use of clearer and purer color and to that elevation of the key of the palette necessary to represent appearances in sunlight. That same genius led him to a recognition of the elusive

character of local color and to the recognition that shadows may not be mere absences of light but simply regions of lesser illumination, where colors interplay on a lower key. It was inevitable that along with increased color-sense the key of the palette should be raised more and more—likewise inevitable, perhaps, that to-day the key of the palette should have sinking tendencies—a natural reaction, the true measure of which we can not yet take.

In the middle of the nineteenth century discussions on the nature of light filled the air (perhaps one should say the ether). Maxwell was about to bring out his famous electro-magnetic theory. Photography had arrived and was being eagerly accepted. Rousseau, to a certain extent Corot, and others of the Barbizon school had gone into the fields and painted effects as they saw them, not as they imagined their ultimate realities to be. Small wonder is it that sunlight and appearance came to mean something in themselves, and small wonder is it that these things should point the way for discerning minds toward a new trend in color. The original scientific labors of Chevreul, Helmholtz, Maxwell and others were ably seconded in spreading the new knowledge in palatable form, especially as it referred to art and painting, by several more popular writers and commentators, chiefly Rood in America and Von Bezold in Germany. These texts, which were published shortly after the Impressionists became consolidated as a group, were translated into several languages and one can not doubt their ultimate direct effect in causing the acceptance of the movement and at least their indirect effect upon the leaders themselves. Strange as it may seem, there is serious question as to whether Monet and some of his contemporaries ever looked into any of these books. They were concerned with painting, not in studying optics, and their ideas of the new trends of color theory were perhaps obtained second-hand over their glasses of wine in studio or café, perhaps through their acquaintance with the enthusiastic Charles Henry. Seurat certainly studied the texts with avidity in constructing his scientific formulas and also Signac, who gave us a record of the movement in his book "From Delacroix to Neo-Impressionism" and who even made a pilgrimage in 1884 to discuss matters with Chevreul in person.

However it was that theory and practise got so closely together in these two great movements, the scientific and the esthetic, it is true that in the origins of the Impressionist movement their fundamental proposals harked back more to Newton and his prism than to Chevreul and Helmholtz. Newton had shown that sunlight on being passed through a prism is spread out into a rainbow band, and he indicated the seven colors of the spectrum, now more often reduced to six. In this rainbow band, as every one knows, these six colors seem to stand out, and hence we speak of the six spectral colors: red, orange, yellow, green, blue and violet. Optically there is a continuous sequence of wave-lengths from the longest to the shortest, and something like a thousand different hues can even be detected by the eye. The selection of six is hence a purely psychological matter. At any rate the idea grew that under the blessing of Newton's experiment with the prism, appearances in sunlight should be represented by the so-called six spectral hues (plus white) in various spottings and juxtapositions. White was to be used to raise the key of the palette toward that of sunlight, and black was to be banned from the shadows where lower lights and complementary colors were to creep in. Thus was the formula set forth for him who could to follow.

The colors in shadows had been observed by Leonardo and later by New-

ton, and the idea of their complementary and partially subjective nature gradually grew through the labors of Brewster, Fechner, Plateau and others. As for the principle of juxtaposition its origin is less distinct. It has been a favorite game of speakers and writers on the subject to trace juxtaposition back to this or that painter—Delacroix, Constable, Turner or Watteau. But it is difficult to tell how much of the germ of the idea was there. While one is in the mood for such a game it is not difficult to further trace the germ back to Leonardo and even to Aristotle. There were among the ancients some very keen observers and often they set forth with inadequate logic what has had to be rediscovered many times since.

One after another of these ideas of contrast, divisionism, spectral hues and high keys was pushed to its limit by those whom we now know as Impressionists and their followers, and so did Impressionism and its attendant "isms" wax and wane. So also did these painters in one experiment after another establish and reestablish the new optics in their own domain, partly through conscious effort to do so, partly through conscious attempt at realizing certain new esthetic aims, and partly through a dim unconscious striving. To a movement which has had, and will continue to have, so much influence on modern art we certainly owe a better and more complete understanding of its optical basis.

THE OCCURRENCE OF OIL AND NATURAL GAS

By Dr. FREDERIC H. LAHEE
DALLAS, TEXAS

In a great many ways we are all directly or indirectly interested in petroleum. Natural gas, widely used for heating and cooking in many parts of the United States, is one variety of petroleum. Crude oil is another; and from crude oil are made such products as gasoline, naphtha, candle wax, lubricating oil, and so on.

From a different angle, many of us possess securities in the form of bonds or stocks in companies organized to drill for petroleum or to refine and market it. Because of these diverse interests which we have in petroleum, we ought to know more about it, how it occurs in its natural state underground, and how it is discovered and brought to the surface.

The name "petroleum" is applied to a group of solids, liquids and gases, all composed of hydrogen and carbon in various proportions. Among the solid forms are asphaltite and ozokerite. Crude oil includes the liquid forms. Natural gas will be used in this article for the gaseous forms, although actually there are other natural gases, such as helium and carbon dioxide.

Crude oil and natural gas are found in minute openings in rocks. These openings are usually the pores between the grains of a sand or sandstone or small open spaces in limestone. That there is considerable space between the grains of a sand may be demonstrated by filling a jar of known capacity with sifted sand of uniform grain. After the jar is full, as much as 30 per cent. of its capacity in oil or water may be poured in to fill the voids between the grains. In its rock form of sandstone, the total pore space is not commonly as high as 30 per cent., for the grains vary in size and the small ones partly fill the spaces between the larger ones. Furthermore, there is usually some mineral substance which has been deposited between the grains, thus helping to bind them together to make the solid rock. In most oil-bearing rocks the pore space amounts to at least 15 per cent. of the rock volume.

In the past history of the earth, broad sheets of sand, mud and limy material, many square miles in extent, were laid down one upon another on the broad shallower parts of the sea floor, in fact much as they are being laid down today; and during the long period since their deposition, these older sheets have been gradually buried, compressed, sometimes hardened into rock, and more or less warped and broken. Thus, we now find that in some regions these rock strata—now called sandstone, shale or mudstone, and limestone—show signs of having been bent in broad wrinkles or folds, which are called anticlines if the fold is arched upward, and synclines if the fold is trough-shaped. The wrinkles in a blanket or in a piece of paper which has dried unevenly after wetting may be compared with the great arches and troughs in rock strata (Fig. 1).

When rock layers have been broken, the masses on the two sides of the fracture have often slipped, one block moving downward with respect to the other. These fractures are called faults, and the rocks which have been broken and have slipped against one another are said to have been faulted (Fig. 1).

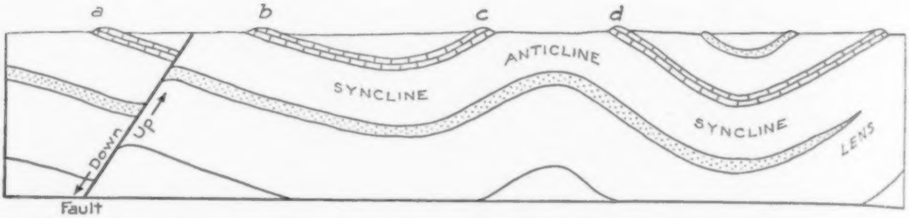


FIG. 1. VERTICAL CROSS SECTION TO SHOW THREE PRINCIPAL TYPES OF GEOLOGIC STRUCTURE WITH WHICH OIL AND GAS MAY BE ASSOCIATED. THESE THREE TYPES ARE THE "ANTICLINE," THE "FAULT" AND THE "LENS." *a, b, c* AND *d* ARE OUTCROPS OF THE SAME ROCK FORMATION WHERE IT APPEARS ON THE SURFACE OF THE GROUND (SEE FIG. 2).

Rock layers are not all of uniform thickness. Indeed, they are much more likely to vary, and they may thin to such a degree that they wedge out altogether, as illustrated in the "lens" in Fig. 1.

Any of these forms in which rock strata are found in nature are called geologic structures. There are many kinds of geologic structures, but anticlines, faults and lenses, with their numerous modifications, are the principal varieties in which we are now interested from the standpoint of petroleum.

It is commonly true that water, usually salt water, is contained in the pores of sandstones and other pervious rocks, at depths of a few score of feet, to several thousand feet below the earth's surface. Quite possibly these porous layers have been filled with water since they were first laid down, but if so the original water has probably been replaced or modified by underground circulation and chemical action.

Where oil and water are associated together, either in an open vessel or in the pores or openings of a body of rock, the oil takes a position above the water, because it is lighter than water. It floats on the water. Also, if gas and oil are contained in a closed vessel, or in a porous rock capped by an impervious layer which prevents escape of the fluids, the gas, being the lighter of the two, will rest upon the oil.

Porous rock strata, such as sandstone and limestone, if overlain by impervious layers, may contain oil and gas where they have been bent in anticlines, or where they have been faulted, or where they wedge out in a direction up the slope (called the "dip") of the beds. These three cases are shown in Fig. 2, where XY is a porous sandstone layer. Note that in each case, true to their specific gravity relationships, gas (finely stippled) is found in the upper part of the structure, oil (solid black) is next below the gas, and water (coarsely stippled) lies below the oil. If only oil and water are present in the pores of the rock, then the oil occupies the upper part of the structure.

To describe the geologic structure in which oil and gas may occur is easy, but to discover such structures is difficult. In the earlier days of geologic exploration for oil, between 1905 and 1920, search was made, on the surface of the ground, for outcropping layers of rock which could be mapped and which, by their distribution and dip (tilt or inclination), indicated the nature of the geological conditions underground (Fig. 1). Thus, the more conspicuous structures were located. But later, as the search for more structures continued, the surface evidences were found to be more and more obscure, and consequently more and more refinement and care were needed in geological work. Recourse was had to diamond drilling to secure core samples of the rocks; to airplane

mapping; and to the application of several kinds of highly technical methods for examining the magnetic, electrical and other physical properties of rocks below the ground surface.

The point to be emphasized here is that the search for new geological structures favorable to oil or gas accumulation becomes increasingly difficult as time goes on. Moreover, no one can tell from the surface whether porous strata are present on the structure, and no one can tell whether such strata, if they are present, will be found to contain oil or gas. The best that any one can do is to map what he thinks may be favorable structures and, basing his judgment on the results of drilling in the surrounding areas, draw some rough conclusions as to the possibilities for porous strata and for oil or gas in these strata. Nothing but the drill will tell the true story. It is well worth remembering, therefore, that any person who, in advance of actual discovery of oil, asserts that he "knows" that oil is present at any particular locality, or beneath any designated spot, is making an unreliable claim; and any written statement which purports to be a geological report is unreliable if, in the same manner, its author professes to have definite knowledge of the presence of oil where oil has not yet been actually seen or produced.

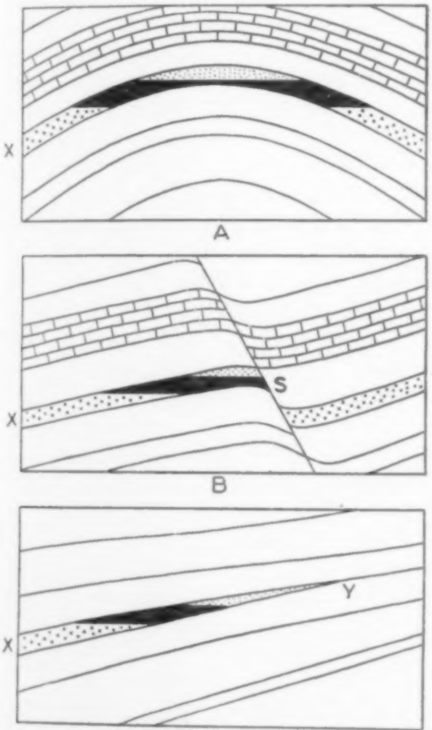


FIG. 2. RELATIONS OF OIL (BLACK), GAS (FINE STIPPLING) AND WATER (COARSE STIPPLING), WHERE THEY ARE FOUND TOGETHER IN A SANDSTONE LAYER (XY), WHERE THIS LAYER HAS BEEN FOLDED IN AN ANTICLINE (A), OR HAS BEEN FAULTED (B), OR WEDGED OUT UPDIP (UP THE INCLINATION OF THE STRATA) (C). NOTE THAT THE GAS IS ABOVE THE OIL, AND THAT THE OIL IS ABOVE THE WATER, ALL IN THE SAME SANDSTONE RESERVOIR ROCK.

Where the oil and gas came from and how they collected where they are now found are two problems not yet settled by scientists. We feel certain that most petroleum is a product from the decomposition of organisms, probably both animals and plants, but we do not yet know the exact processes of this decomposition; and we are fairly certain that the oil and gas in many localities where they now occur have gathered there by moving through rock pores or other rock channels from the surrounding region, yet we do not know just how they have moved. For the present the facts concerning the origin and migration of petroleum remain in obscurity.

Formerly, before the true nature of oil occurrence was understood, the prevailing idea was that it was practically unlimited in supply and that it moved from place to place more or less as underground rivers. What ideas were held were for the most part rather hazy. But now, with a vast store of information derived from tens of thousands of wells, we know that both oil and gas, even though they are in the small pores of rocks, occur as isolated, definitely bounded accumulations, often referred

to as "pools" or "fields." We also know that within each such pool the oil and gas are under pressure, due partly to the weight of the overlying rocks and partly to hydrostatic pressure from the water flanking the oil within the porous reservoir rock. And finally we know that the gas, while under sufficient pressure, serves as a most valuable agent in moving oil through the pores of its containing rock to the lower end of the well, and then in lifting this oil through the well to the surface. In this way the gas, as natural energy within the reservoir, is of very great importance in facilitating the extraction of oil from below ground.

Any method of development—and by "development" we mean drilling the wells and producing the oil—which dissipates the reservoir energy, by wasting the gas, or taking the gas out of the pool unequally, or taking it out too rapidly, reduces the efficiency of the energy available in the reservoir and thus reduces the quantity of oil which will eventually be recovered. Wide experience in many regions has shown that evenly spaced wells throughout the area of the pool are more conducive to maintenance of reservoir pressure than uneven spacing where the wells are crowded together in some places and wide apart in others; and experience has also shown that the decline in reservoir pressure which is generally observed in producing fields can be retarded and kept more uniform by regulating the flow of oil in all the wells instead of allowing them to produce wide open. A gusher, pouring out hundreds or thousands of barrels per day, is a thrilling sight, particularly for the owner, but as long as it flows unbridled and without consideration of its relation to other wells in the field, it is trespassing on the prospects and the rights of other owners in the pool, both owners of leases and owners of royalty alike.

Unless a pool is drilled and operated systematically and efficiently, with full regard for the proper utilization of the reservoir energy, not only are the individual rights of the owners jeopardized, but—more important—oil in large quantities is left underground where it can never be recovered. No matter how carefully the wells are drilled and operated, there is always a certain percentage of the oil which can not be extracted, and which is therefore left in the pores of the reservoir rock; but by poor practises in drilling and operating, a much larger proportion of the oil originally present in the pool may be permanently left in the ground.

Petroleum is one of our greatest national resources. It is a diminishing asset which we can not afford to waste. It should be wisely produced and wisely utilized. Not only for the sake of property-owners in the pool, but also as a national obligation, every oil and gas pool merits the application of orderly and scientific methods of development.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

MEASURING A MILLIONTH OF A SECOND

By Dr. J. W. BEAMS

PROFESSOR OF PHYSICS, UNIVERSITY OF VIRGINIA

ONE of the surprises encountered by the student in science is his first realization of the amazing speed with which some of the elementary processes in nature occur. Accustomed as he is to observing things through his senses, it naturally imposes a considerable tax upon his imagination to visualize the rapidity with which these elementary phenomena are taking place round about him. For example, the average human eye can not distinguish between two light flashes that occur in less than about one sixteenth of a second of each other. In fact, it is this property of the eye that makes possible the smooth continuous moving pictures, or causes the familiar electric light or neon sign to seem continuous without flicker, even though their light usually consists of a series of flashes. On the other hand, experiments have shown that the actual time required for the light itself to stimulate the retina, or, in other words, to be absorbed by the eye, must be millions of times less than one sixteenth of a second.

The ordinary stop-watch with which we are accustomed to making our precise measurements of the time, between our every-day events, is seldom graduated in divisions of less than one tenth of a second because of the inability of the average individual to operate it in shorter times than this. However, when we compare this one tenth of a second, or the shortest time we could possibly measure with our ordinary stop-watches, with the time required for atomic or molecular interaction to take place we find that the former is very large indeed. For example, in the air that surrounds us the average time between two collisions of a molecule is about one five-billionth of a second, and the average time required for this same molecule to give off light after it is stimulated by means of, say, lightning or an electric spark, is around a hundred millionth of a second. In other words, these events take place in about the time it takes a fast rifle bullet to penetrate one one-hundredth of the thickness of a page of writing paper.

It therefore long ago became apparent to the physicist that if complete studies of many natural phenomena were to be made it would be necessary to devise direct methods of distinguishing between two events happening within a fraction of a millionth of a second. In other words, instruments must be constructed capable of recording events faster than they occur in the phenomena under investigation. Fortunately for this purpose nature has endowed us with some phenomena that take place much more rapidly than others, so that those occurring in shorter times may be utilized to study those of longer duration, or the faster moving things may be used to measure the slower ones.

At this time I can outline only one or two of the numerous methods used by the physicist for observing things that happen in these extremely short times, or to indicate briefly even a minute portion of the vast amount of valuable in-

formation both from the scientific and practical standpoint obtained by their use. An experiment any one can try is to look at the reflection of a light in a hand mirror and to rock the mirror rapidly. If the light is steady, like that of a candle, the reflection is strung out into a streak. On the other hand, if the light is not steady, like that of the familiar red neon sign, a row of separate images appear as the sign is lighted and extinguished. This results from the fact that as the mirror is turned the successive flashes of light from the sign enter the eye from different directions and hence fall at different places upon the retina.

If, instead of looking at the reflected light from the turning mirror, it is allowed to enter a camera, each flash falls in a different position on the photographic plate so that the photograph shows a row of pictures of the separate flashes. If then we know how fast the mirror is being turned we can find the time between the flashes. The faster the mirror is turned obviously the greater the distances between the images on the retina or the pictures on the photographic plate. This device of the rotating mirror is one of the simplest and most useful at our disposal, provided the mirror be spun with very great speed.

To do this we mount the mirror, which is usually made of stellite, on a cone-shaped piece of metal called a rotor, that looks something like a schoolboy's spinning top. This rotor fits into a similar hollow metallic cone containing openings from which jets of air at high pressure are blowing. However, the rotor is not blown out of the cone but floats on the air like a ball on a fountain jet, while small grooves on it conspire with the air jets to set it spinning. Rotors of this kind have been spun up to a half million revolutions per minute. To study an electric spark, for instance, the light of the spark is thrown into a camera by the spinning mirror or we may watch it in the mirror by the eye. We can make the image of the spark move so fast that two views of it one one-hundred millionth of a second apart appear as separate. With the aid of this rotating mirror it is found that the electric spark starts as a narrow thread and expands radially; also that the different colors of its light, called spectrum lines or bands by the physicist, do not all appear simultaneously but come off at different times, the light from the air atoms and molecules appearing before that from those of the metallic electrodes.

Light, together with the family of phenomena to which it belongs called electromagnetic radiation, travels with a velocity in excess of 180,000 miles per second. These are the fastest moving forms of energy known to man. Yet, the rotating mirror just described turns through a measurable angle while light travels less than ten feet. As a matter of fact, the velocity of light can now easily be demonstrated and roughly determined, utilizing a light path within the confines of an ordinary room.

We could spin these mirrors faster if our materials were strong enough, but at higher speeds the rotor would be torn apart by the very great centrifugal force developed. Incidentally, these rotors have found application as a centrifuge for separating heavy liquids from light ones, as in the case of the cream separator. So great is the centrifugal force that the outward pull on the material is more than a million times its weight. Under such conditions, for example, cream should rise from milk in a very small fraction of a second.

Fast as the rotating mirror is, there are devices which work still more quickly. You are probably familiar with the fact that the vibrations of light are crosswise, like waves in a stretched cord, not forward and backward like sound waves. Ordinary light is a mix-

ture of vibrations in all directions, at right angles to its line of propagation, but certain crystals can single out one of these directions. If a stretched horizontal rope is confined between two vertical guides you can send an up-and-down wave along it but not a crosswise one. Our crystal devices, called Nicol prisms after their inventor, put the light waves, so to speak, between guides. If we send a beam of light upon two such prisms crossed at right angles no light will come through, although each prism by itself seems transparent.

If we put certain transparent liquids, such as water or carbon disulfide, in the light path between these two crossed Nicol prisms nothing is changed, but if an electric field is properly applied to the liquid, light will come through. This phenomenon is called the Kerr effect, after its discoverer, and the arrangement in which the electric field is applied to the liquid is called a Kerr cell. Effectively, then, this arrangement of a Kerr cell between the two Nicol prisms is a light shutter, because it allows light to pass when the electric field is applied and extinguishes or stops the light when the electric field is removed from the Kerr cell. The time required for this Kerr effect to take place or to vanish after the electric field is applied or removed in a liquid is very short; for example, in carbon disulfide it is probably less than a billionth of a second.

It is this property of the Kerr cell light shutter of responding almost instantaneously to electrical control that makes it, in its variously modified forms, of great value in studying short-time phenomena as well as in immediate practical applications. It has been used in many researches, including studies of the electric spark and other discharges; studies of the time element in fluorescence; studies of the time required for light to eject electrons from a photosensitive metal, or in other words the time required for the photoelectric effect to take place; and even for measuring the velocity of light. Among its practical uses is its application to television.

Time does not permit a discussion of the many other beautiful methods, such as the electric or Lichtenberg figures, cathode ray oscillograph, or Wilson cloud chamber, any of which can record events that happen in times much shorter than a millionth of a second. However, in closing, it may be of interest again briefly to call your attention to the difficulty of conceiving of such short times as a millionth of a second. For example, an automobile running a mile a minute would move about a thousandth of an inch in this time, while a fast airplane could travel less than one tenth of an inch. Yet difficult as it is to imagine, we now have at our command several different methods of recording events that happen in considerably less than a hundred-millionth of a second; or, in other words, we now have methods of measuring a millionth of a second with as much precision as we can measure a minute with the best stop-watch or ten minutes with an ordinary watch.

SLEEP

By Dr. S. W. RANSON

PROFESSOR OF NEUROLOGY AND DIRECTOR OF THE INSTITUTE OF NEUROLOGY, NORTHWESTERN UNIVERSITY

Why do you spend about eight hours a day or one third of your time in sleep when there are so many interesting things to do for which you can find no time? The obvious answer that unless one gets adequate rest one soon becomes

exhausted and life not worth living justifies this use of time, but it does not explain how and why sleep comes. What makes consciousness disappear, the muscles relax, the heart rate decrease and the whole organism, body as well as brain, begin to repair the damage sustained during the preceding day and to lay up new stores of energy for the morrow? Think about this some wakeful night when you lie with muscles tense and thoughts whirling in uncontrollable eddies through the long hours that the much-needed rest escapes you. I doubt if you will find the answer, for the problem still puzzles the scientists who have given most thought to its solution.

Many theories have been advanced, but they are all unsatisfactory. I shall mention only two of them. It has been supposed that during activity fatigue substances are produced and accumulate in the blood and that these have a narcotic action on the brain. The accumulation of these substances would thus periodically induce sleep, during which they would be excreted from the body, thus allowing for the return of the waking state. But against this theory are the facts that sleep, as in an afternoon nap, may come when there is little fatigue, that extreme nervous fatigue often leads to insomnia, and that normal sleep, unlike ether narcosis, is easily interrupted by noise or other disturbances.

Yet it is a matter of common observation that sleep ordinarily comes easily to one who is physically fatigued. A soldier after a long march finds it difficult to remain awake on the eve of battle. In laboratory tests it has been found that after two or three days of continuous wakefulness the tendency to sleep is almost irresistible and if the subject of the experiment is allowed to sit quietly in a chair he will drop off at once. Yet if kept awake by frequent prodding he is mentally alert and capable of solving problems in a normal manner. It is certain that under normal conditions sleep comes long before a state of exhaustion is reached that greatly impairs efficiency. The change from the waking to the sleeping state is abrupt and can not be explained by the gradual accumulation of waste products of activity.

Another theory, which at one time received considerable attention, is that during sleep the conduction pathways in the nervous system are broken by the retraction of small contact points between the neurones which are the conducting units of which the nervous system is composed. If this occurred it would stop nervous activity just as effectively as pulling all the plugs from a switchboard would stop all communication over that telephone system. But there is no evidence that such retraction occurs.

The habit of sleeping at night is acquired early in life. It is the first habit which a mother tries to have her baby acquire. Many animals, like new-born infants, have several periods of alternating wakefulness and sleep in twenty-four hours. White rats have ten such periods of rest, totaling, on the average, fourteen hours out of every twenty-four, the greater part in the daytime. The ringed snake is a good sleeper. It awakes at noon, is active for one and a half hours and then retires and is perfectly quiet until the following noon.

In man the habit of nocturnal sleep seems to be definitely related to the importance of visual sensations. Rats which depend chiefly on the sense of smell can afford to take naps in the daytime and make up for lost time by foraging at night.

Dogs are active in the daytime and sleep at night, partly because their activity is guided largely by information gained through their eyes and partly because their habits are adjusted to correspond with those of men. But Kleitman has shown that if the superficial layer of gray matter, which is known as

the cerebral cortex, is removed from a dog's brain the animal loses the habit of nocturnal sleep and has five or six periods of sleep alternating with activity each twenty-four hours. When awake these dogs are restless and walk around and around in the cage.

These observations are significant for our problem. They show that the habit of sleeping at night is dependent on the cerebral cortex. It is not surprising that the removal of the cortex should disturb the rhythm of the sleeping and waking states, for it is this layer of gray matter on the surface of the cerebral hemisphere which is the part of the brain that is responsible for what we call consciousness. One might, therefore, not have been greatly surprised if these dogs, deprived of their cerebral cortex, had slept all the time. But since they had frequently recurring periods of wakefulness and activity it is clear that sleep must involve something more than the inhibition of cortical activity. Other parts of the brain must also be quiescent in sleep.

The cortex is the covering of the cerebral hemispheres which form the greater part of the forebrain; behind this there is the midbrain and still behind that is the hindbrain. It has recently become known that there is a small region in the midbrain near its junction with the forebrain that has a very important relation to sleep.

This is the region involved in a form of sleeping sickness known to physicians as encephalitis lethargica. Although there are records of epidemics in the past which may have been manifestation of the same disease, it first became known to modern medicine as an epidemic which broke out in Europe during the world war. This epidemic started in Vienna in 1916, and became wide-spread in Europe the following year. In 1918 the disease appeared in England, and in March, 1919, the first cases were reported in the United States. Since then cases have appeared sporadically in almost every country; and this summer there has been a fresh outbreak of the malady in St. Louis.

With the onset of the illness the patient becomes drowsy and if left to himself sleeps day and night. Yet he is not comatose, but can be easily aroused much as from normal sleep. There is usually some paralysis of the muscles which move the eyes, indicating that the portion of the brain from which the oculomotor nerve arises has been damaged. Post-mortem examination of such cases has shown wide-spread inflammation of the brain, but the most severe damage is at the junction of the midbrain and forebrain just in front of the origin of the oculomotor nerve, which supplies the eye muscles. Because of the frequency with which drowsiness and pathologically prolonged sleep are associated with paralysis of the eye muscles in this disease, and the location of the chief lesions and most severe damage just in front of the origin of the oculomotor nerves it has been assumed that this region at the junction of the forebrain and midbrain has some special significance for the regulation of sleep.

Von Economo, a Vienna neurologist, was the first to draw this conclusion from a study of cases of encephalitis lethargica. He spoke of this region as a sleep center; but by this he did not mean to imply anything more than that it was in some way concerned with the regulation of the periodic alternation of the waking and sleeping state. This supposition is strengthened by the fact that cases are on record where this same region has been destroyed by hemorrhage or abscess or has been pressed on by tumors and these patients have slept continuously for weeks at a time. Neurologists now recognize pathologically prolonged sleep as a symptom pointing to a damage of this part of the brain.

Recently we have been able to produce

a similar condition experimentally in cats by destroying a small sharply localized area in this part of the brain. While this was being done the animals were under deep anesthesia so that neither at the time of the operation nor afterward did they suffer pain. In making these lesions we have used an apparatus which makes it possible to place the tip of a needle-like electrode at any desired point in the brain. Through this electrode, which is insulated, except at the end, there is passed a very weak electric current that slowly destroys the brain substance for a short distance around the end of the needle, thus making a small spherical lesion.

When by this method we have placed small lesions on each side of the midline in the region corresponding to von Economo's sleep center, the cats have slept almost continuously for days or weeks following the operation. They can, without much difficulty, be wakened and made to walk about the room or jump from a table. But they are disinclined to move about, take no interest in their food nor in a mouse placed before them. As soon as they are left alone they drop off to sleep again. In many ways they present a striking resemblance to patients with encephalitis lethargica.

We have not been able to produce this condition of prolonged sleep by similar lesions in other parts of the brain, and it now seems certain that this particular region has special significance for the regulation of sleep. Why a lesion so placed should upset the normal rhythm of activity and make the animal sleep almost continuously we do not know any more than we know why patients with similarly placed lesions are so drowsy. But these animals furnish a means of attack on some of the problems presented by sleeping sickness and excellent material for studying the nature and cause of sleep.

TULAREMIA

By Dr. EDWARD FRANCIS

MEDICAL DIRECTOR, UNITED STATES PUBLIC HEALTH SERVICE, WASHINGTON, D. C.

I ASSUME that by this time you all know what tularemia or rabbit fever is—almost everybody in the United States does. If not, then you had better ask some housewife to tell you about it before you shoot your next rabbit. It is one of our most popular diseases in the fall of the year when everybody wants to shoot a rabbit. About one thousand persons contracted tularemia, or rabbit fever, in the United States during the past year from skinning or dressing wild rabbits.

Well, what is tularemia anyway? It is a disease of wild rabbits which causes their livers and spleens to become spotted all over with a million small spots and causes the death of the rabbit. In addition, the germs grow and multiply in every part of the rabbit's body, including the blood and muscles. Ordinarily only about one in every hundred of the wild rabbits is infected, but, sometimes, the disease becomes epidemic among them and then we see dead rabbits lying everywhere.

The liver of an infected rabbit is recognized by the spotted appearance of its surface. A million small round spots become plainly visible on the liver of an infected rabbit on the third or fourth day of its illness, but these spots are too tiny to be seen on the first and second days of illness; therefore, if a rabbit is shot on the first or second day of illness the liver, although diseased, will appear healthy.

Hunters who shoot and dress rabbits

become infected in dressing them. Their bare hands become covered with blood when they pull out the livers and spleens. If by chance there is an open cut or sore on the hands, the infection travels from the rabbit's blood or liver into the wound on the man's hand and gives him tularemia or rabbit fever. When a rabbit is shot the bones often become shattered into small fragments by the shot; if, in dressing a rabbit, one of these sharp fragments pierces the skin of a man's hands the infection enters at that place. Sometimes the infection penetrates the normal skin of the hands in the absence of an evident wound.

Then, in about two or three days illness begins with a headache, chilliness, vomiting, aching pains all over the body and fever. The patient thinks he has the "flu" and goes to bed. The sore on the hand develops into an ulcer. The glands at the elbow or in the armpit become enlarged, tender and painful, and later may develop into an abscess. There is sweating, loss of weight and debility. Illness lasts about three weeks and is followed by a slow convalescence covering a period of two or three months. Most cases recover without any bad after effects, but about five cases in every hundred die, especially if complicated by pneumonia.

One who has recovered from an attack of tularemia need not fear a second attack, because then he is immune against the disease. Market men who skin and dress rabbits year after year contract the disease only once. Therefore, if there is some job requiring the handling of wild rabbits give the job to an immune—to some one who has had the disease once.

Prevention is the keynote of modern medicine. Keep your bare hands out of a wild rabbit. Rubber gloves afford sure protection to hunters, market men, cooks, housewives and others who must dress wild rabbits, but remember that sharp fragments of shattered bones can easily pierce a rubber glove and puncture the hand. The liberal use of soap and water and disinfection of the hands are recommended to remove blood from the hands or even when the hands have only come in contact with the rabbit's fur.

Thorough cooking of all wild game, especially rabbits, is essential. Thorough cooking will render infected rabbit meat entirely harmless for food, because the germs are easily killed by the heat of thorough cooking. But, if any red juice is allowed to remain about the bones the germs will remain alive and virulent in that red juice. Eating of insufficiently cooked wild rabbit meat has caused three serious outbreaks in each of three families who ate the meat. Three members of one family died. Three died in another family and two died in the third group.

A warning to the poor sportsman is necessary. He should not shoot the rabbit which is on the end of his gun—that one is probably a sick one. Let him shoot his rabbits on the run; shoot only the lively ones. Avoid the rabbit which has been found dead, and the one which the cat or dog has brought in, and the one which a boy has killed with a club—they are all probably sick. The women of the country are coming to the rescue. They are telling their sportsman husbands to bring home the birds but to let the rabbits lie as they fall—do not bring home the rabbits.

In all that I have said you will notice that domesticated rabbits have not been mentioned. The disease has never been found in rabbits raised under domestic conditions, as in rabbitries and hutches, and sold for food and sold for pets. These rabbits, however, are just as susceptible to experimental infection in the laboratory as are the wild rabbits.

A fisherman in Texas found a dead jack-rabbit, which he cut up into some small pieces, putting one piece on each

of his fish hooks for bait. He caught no fish, but three days later he went to the hospital with tularemia. A farmer in Minnesota cut up a rabbit which he had found dead on his farm and fed it to some silver foxes which he was raising in a pen—expecting that some day he would sell the silver fox furs for some lady to wear around her neck. But, fifteen days later, the farmer was dead from tularemia. A farmer in Montana was sick. He called his doctor, who drove 75 miles to see him. The diagnosis was a mystery until the farmer, pointing out of his window and up the slope of a hillside, called the doctor's attention to many white spots on the hillside and added that each white spot was a dead snowshoe rabbit. That farmer was the first case of tularemia in Montana. Making a diagnosis of tularemia is like working a crossword puzzle; the trick is to find the letters which spell "rabbit."

A golf champion of national reputation was wintering in Florida and was playing a golf match when suddenly he realized that his golf game was slipping away from him. Spying a dead rabbit lying on the golf course and being a bit superstitious he quickly pulled out his knife, cut off the rabbit's left hind foot and secretly slipped it into his pocket, expecting a change of luck. But, in the excitement of the quick amputation, a sharp fragment of rabbit bone punctured the golfer's finger. That was enough, because two days later the golfer went to the hospital for a month's illness with tularemia. *Moral:* Know your rabbit, brother!

Up to this point I have spoken only of wild rabbits, but there are ten other kinds of American wild life that have given tularemia to people. I will name them: Wood-ticks, horse-flies, tree squirrels, quail, sage-hens, opossums, groundhogs, muskrats, skunks and coyotes.

Wood-ticks of Montana and the surrounding states become infected by biting wild rabbits. They then convey the infection to man by biting him beneath his clothing. Dog-ticks in ten of our southern states not only bite dogs, but they bite rabbits and then the ticks convey the infection to people whom they bite. Ticks are notorious for their ability to transmit disease because of their habit of imbibing at every bar they come to, and when the list of their drinking places includes both rabbit and man then the man goes to the hospital. Blood-sucking flies in Utah and the surrounding states bite horses and cows, but they also bite rabbits and man, thus conveying the infection from rabbits to man.

Quail live on the ground and they associate with rabbits and become infected by ticks, which first bite the rabbits and then bite the quail. During the hunting season man shoots the quail, and in dressing them he becomes infected through his hands just as he does when he dresses a rabbit. Sage-hens, like quail, live on the ground in close relation to rabbits, and therefore they exchange ticks with the rabbits. This may cause the sage-hens to become infected, and then they transmit the infection to the people in Montana who dress them.

The red squirrel, the gray squirrel and the black squirrel have caused tularemia in people who dressed them. Opossums, in some sections of the country, are skinned and dressed for food. If they happen to be infected with tularemia they pass the infection on to the person who dresses them, just as an infected rabbit does. Ground-hogs and rabbits may come together in the same holes in the ground. If infection should travel from the rabbit to the ground-hog then the boy who skins the ground-hog for its fur becomes infected through his hands. Muskrats are skinned for their fur and are eaten in large numbers under the guise of marsh rabbit. If infected, they transmit tularemia to the one who skins them. Skunks are skinned for furs. If

they happen to have tularemia they pass it on to the person who skins them. Coyotes contract tularemia from the infected rabbits which they eat. Man becomes infected when skinning an infected coyote.

Certain animals are rabbit eaters. If they should eat an infected rabbit and immediately bite a man the infection which lurks in their mouths and about their teeth is conveyed to people whom they bite. People have contracted tularemia from the bites of cat, skunk, coyote, Montana ground squirrel, opossum, dog or hog. Two people were scratched by cats and another was scratched by a tree squirrel.

Human cases have been recognized in forty-six states of the United States and in the District of Columbia. The only states which have not recognized cases are Vermont and Connecticut. The disease was reported in Japan in 1925, in Russia in 1928, in Norway in 1929, in Canada in 1930 and in Sweden in 1931. No other country has recognized the disease.

CASES REPORTED IN THE UNITED STATES

		Cases	Deaths
Previous to	1924	15	2
1924, 1925 and	1926	308	11
	1927	251	10
	1928	350	10
	1929	462	36
	1930	659	37
	1931	675	32
	1932	933	41
	1933	1021	....
		3,653	179

The disease was named tularemia after a county in California—Tulare County—where it was first discovered in 1910 by Dr. George W. McCoy, of the United States Public Health Service. The disease therefore bears the label "Made in America," and it has been elucidated from beginning to end by American investigators alone.

COMPARATIVE VALUES OF AMERICAN MAMMALS, 1726 AND 1753

By LEILA G. FORBES and HUGH UPHAM CLARK
WASHINGTON, D. C.

THE sharp rise in the prices of our natural products and of imported commodities between the years 1726 and 1753 is well brought out by an interesting official document from the early records of the Province of the Massachusetts-Bay in New England which is now in our custody.

This document, given in full herewith, shows the increase in value of the more important native mammals, and also of the more important articles of trade. We have given the latter in order that they may be compared with the former.

The Treaty at Casco in 1726 referred to was the Conference between Lieutenant-Governor William Dummer of the Massachusetts-Bay in New England and others, and the Eastern Indians, held from July 16 to August 11, 1726. The proceedings of this conference are printed in full in the Collections of the Maine Historical Society, Portland, Maine, Vol. 3, 1853, pp. 377–405.

The conference was for the purpose of ratifying the treaty of peace drawn up at Boston in the preceding winter. This treaty, "Dated at the Council-Chamber in *Boston* in New-England, December 15, 1725," was printed by Samuel Penhallow in his "History of the Wars of New-England with the Eastern Indians," etc., Boston, 1726. In it we read (p. 124) "That all Trade and Commerce which may hereafter be allowed betwixt the *English* and the Indians shall be under such management and Regulation, as the Government of the *Massachusetts* Province shall direct."

In the proceedings of Friday, August 5th, 1726, we find (p. 394):

Lt. Gov. of the Massachusetts. The Articles of the Treaty shall be distinctly read, and faithfully Interpreted to you.

While the Articles were in Reading, Immediately after the Article respecting Trade, the Indians by their Speaker *Loron*, acquainted the Lieut. Governour that they had been told the Prices of Goods would be raised when the Ratification was over.

The Lieut. Governour answered them, that they might be assured, that the Goods always were, and still should be, bought with ready Money, and that the Government would not make any new Advance on their goods, and for a Proof of it, they would always be sensible and find that the Government would supply them Cheaper than any other People whatsoever, That they are Acquainted with the Nature of Markets, that they are sometimes higher and sometimes lower.

After the Articles were read, and the Interpreters had finished, *Loron* made a second motion, and informed the Lieut. Governour, that it had been reported that the Articles of Peace which were delivered to him, and the other Delegates at *Boston*, were not of the same Purport with those they Deposited and left in the Hands of the Government, and therefore desired that an Exchange might be made of the Articles they carried with them to *Penobscut*, with those left in the Hands of the Government, in order to their being Enabled to confute such Reports: Which was readily granted them by the Lieut. Governour, to the apparent Satisfaction of the whole Tribe. The Articles being Interpreted to the Indians, the Lieut. Governour asked them whether they thoroughly understood them.

Indians. We perfectly understand them all.

The document bears on the back the annotation—

"Publick Papers
Indian Affairs
1726 . 1753"

Prizes of Furs, allowed the Jndians, in the Year 1726 when L^T Governor Dummer had a Treaty at Casco and what the Jndians then paid for their Goods in Lieu thereof, with what's allow'd them at present for their Furs, and an account of what they now pay for Goods in Exchange

Prizes of Goods sent the Jndians in 1726	Prizes of Goods sent the Jndians in 1753	Prizes of Furs & Beaver purchas'd of ye Indians in the Year 1726	Prizes of Furs allow^d the Indians in the Year 1753
Rum 5/ pr Gallon	.....16/ pr gallon	Spring Beaver 8/pr plus	.....40/ pr plus
Bread 50/ pr hund^d	.....£9 pr hundred	Fall Ditto 6/ pr plus	.....25/ pr plus
Corn 6/ pr bushell	.....28/ pr bushell	Stage Ditto 4/ pr plus	.....15/ pr plus
Pipes 6/ pr Groce	.....30/ pr Groce	Fishers 6/ piece	.....40/ piece
Tobacco 10^d pr pound	.....3/ pr pound	Catts 6/	.....25/
Oznabngs 2/9 pr Ell	.....10/ pr Ell	Ottors 6/	.....40/
½ thicks 4/6 pr Yard	.....15/ pr Yard	Minks 20^d	.....8/
Blankets 21/ apiece	.....£4 apiece	Bears Large 3/6	.....25/
Hatchets 5/6 apiece	.....20/ apiece	Musquash 4^d	.....3/
Molasses 3/8 pr Gall°	.....14/ pr gallon	Castorum 2/ pr plus	.....15/ pr plus
Broad Cloth 33/ pr yard	.....£4 pr yard	Moose 10/ piece	.....50/ piece
Strouds £17 apiece	.....£60 apiece		
Pork £7 pr barrell	.....£25 pr barrell		
Kegs 2/ apiece	.....5/ apiece		
Shot 78/ pr hund^d	.....£12 pr hund^d		
Powder 18£ pr bb.	.....£50 pr barrell		

Septem^r 15^th 1753
Errors Excepted
pr Jn° Wheelwright

Explanation of Terms

Bear.—The black bear, *Euarctos americanus* (Pallas).

Beaver.—*Castor canadensis* Kuhl.

Castorum.—A reddish brown substance consisting of the preputial follicles of the beaver and their contents dried and prepared for commercial purposes. It has a strong, penetrating, and persistent odor and was formerly in high repute as a medicine, later being used chiefly for perfumes.

Catts.—*Lynx canadensis* Kerr and *L. rufus* (Schreber).

Fisher.—*Martes americana* (Turton) or *M. pennanti* (Erxleben).

Half-thick.—A kind of coarse cloth. Mr. J. Leander Bishop mentions half-thicks among the large quantities of different kinds of cloth imported in colonial days from England (A History of American Manufacturers from 1608 to 1860, Philadelphia, 1861, p. 344).

Mink.—*Mustela vison* Schreber.

Moose.—*Alces americana* (Clinton).

Musquash.—The musk-rat, *Ondatra zibethica* (Linne).

Ottors.—Otters; *Lutra canadensis* (Schreber).

Oznabngs.—Osnaburgs; osnaburg was a coarse cloth made of cotton, or of flax and tow, first manufactured at Osnaburg in Germany.

Plus.—According to Dr. Hartley H. T. Jackson this is the value, or equivalent, of one prime beaver skin.

Strouds.—A stroud was a blanket made of strouding, a coarse warm cloth, used in trading with the Indians.

BUST OF PROFESSOR ALBERT EINSTEIN

Executed by Jacob Epstein, presented to the Hebrew University by Hiram J. Halle, of New York City, on the occasion of the dedication of the Einstein Institute of Physics.

THE PROGRESS OF SCIENCE

THE EINSTEIN INSTITUTE OF PHYSICS AT JERUSALEM

IN 1924 a long procession of motor-cars wound its way up Scopus, "the mount of gazing," just outside Jerusalem, where the first scientific address was to be delivered under the auspices of the infant Hebrew University, whose formal dedication by the late Earl Balfour was not to take place until the following April. Crowds of peasants had collected from the neighboring Arab villages in order to see and hear one of the greatest scholars in the world, Professor Albert Einstein.

Two years were to elapse after that first lecture on physics until, in 1926, in connection with the visit of Dr. Leonard Ornstein, well-known physicist and rector of the Utrecht University in Holland, it was definitely decided to establish an Institute of Physics at the Hebrew University, which last month was dedicated as the Einstein Institute of Physics in the presence of a distinguished group of governmental officials, academic staff and student body of the Hebrew University and visitors from America and abroad.

A bust of Dr. Einstein executed by the American sculptor, Jacob Epstein, and presented to the institute by Hiram J. Halle, of New York City, forms one more link between the great scientist and the university which has the honor of having as one of its rarest possessions the original manuscript on "The Theory of Relativity," a gift of Dr. Einstein.

Situated on a steep slope of the northeastern boundary of the university grounds, which themselves overlook all Jerusalem, the Einstein Institute commands probably the most historic view of which any campus can boast. The eye roams as far as the Jordan Valley and the deep basin of the glittering Dead Sea; across the intervening bowl of the Jericho foothills, lying below the Jerusalem range, loom the purple mountains of Moab. Stately old trees surround the institute, all the more remarkable in a land laid waste and barren through centuries of warfare.

The new Institute of Physics is not designed merely to fill an urgent need of the university as such, even though the methods applied to physics are beginning to enter into every branch of scientific investigation; it is of equal importance for the general research work which is going on all over Palestine. It will house the first materials testing laboratory in Palestine, a factor of extreme importance in a country with such intensive building activity, where hitherto no facilities have existed for examination and testing of building materials by scientific methods. The institute will be called upon to solve certain questions which can be answered there better than elsewhere on account of its varied climatic conditions. For example, an astrophysical observatory, which would carry on its work under exceptionally favorable conditions, is to be attached to the spectroscopical laboratory. Few countries have so transparent an atmosphere as Palestine. As in more northern latitudes the air has little dust and, in contrast to the tropics generally, is free from moisture. For the greater part of the year the sky is cloudless and presents a picture of undimmed radiance. Moreover, there is no other observatory in the whole of the Near East. The nearest on European soil is at Athens.

Dr. Ornstein, who is a member of the board of governors of the Hebrew University, supervised the plans for the construction of building along the lines of the most up-to-date European institutes. In November, 1928, building operations commenced, culminating in the present U-shaped building, which was dedicated on March 11. The cen-

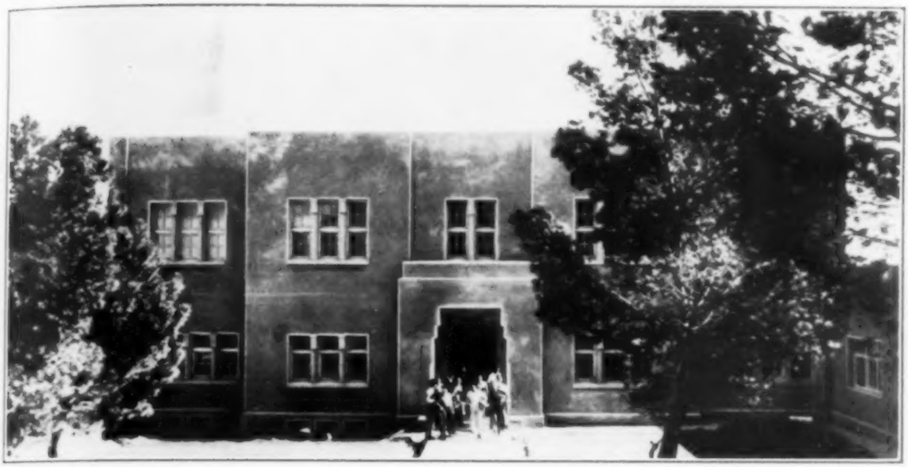
tral portion contains two stories and a basement. There are also two wings of one story each. Classrooms, lecture rooms, offices, photograph rooms, battery and dynamo rooms, five research laboratories and a basement for spectroscopic experiments are included. Announcement was made at the dedication exercises that work has already been commenced on one of the two wings.

It is interesting to note that two women, Mrs. Helena Davis, of London, England, and Mrs. Dora Monness Shapiro, of New York City, have made these two wings possible. Each of them this year has contributed funds for the erection of further laboratories. Mrs. Shapiro and her late husband were responsible with Philip Wattenberg, also of New York City, for the erection of the original building at a cost of approximately £15,000 and for a ten-year maintenance fund for the entire building. Construction of the second wing of the building will be complete and two additional laboratories and offices will be available for extended research and instruction. The new Abraham and Helena Davis Laboratory will be used in connection with further accommodation needed for the increased number of students in the Division of Biological Studies.

The present equipment is modest and in keeping with the youth of the university as a whole. This month marks the ninth anniversary of this "first University of the Jewish people." Great tasks

AERIAL VIEW OF THE HEBREW UNIVERSITY ON MT. SCOPUS

IN THE FOREGROUND OF THE PICTURE MAY BE SEEN THE JORDAN VALLEY LYING 3,000 FEET BELOW THE STAGE OF THE MINNIE UNTERMYER MEMORIAL OPEN-AIR THEATER. ON THE OTHER SIDE IN THE REAR IS THE DAVID WOLFSOHN MEMORIAL LIBRARY, OVERLOOKING THE OLD CITY OF JERUSALEM. THE UNIVERSITY IS SITUATED ON MT. SCOPUS, PART OF THE RANGE OF THE MOUNT OF OLIVES. AT THE RIGHT FOREGROUND, BACK OF THE NEWLY PLANTED FOREST, IS SHOWN A REAR VIEW OF THE EINSTEIN INSTITUTE OF PHYSICS.



THE ENTRANCE TO THE EINSTEIN INSTITUTE OF PHYSICS

await the scientific scholars who will take up their work in this building on the edge of the desert, named for the greatest physicist of our times.

A new and important step in the development of science in the Near East has been taken—in the beautiful and lucid words of the Bible, "Migdal Zofim al Har-ha-Zofim," meaning "A watch tower has been erected on the Mount of Gazing," Mount Scopus.

J. B. K.

THE HEAVY HYDROGEN SYMPOSIUM AT THE ST. PETERSBURG MEETING OF THE AMERICAN CHEMICAL SOCIETY

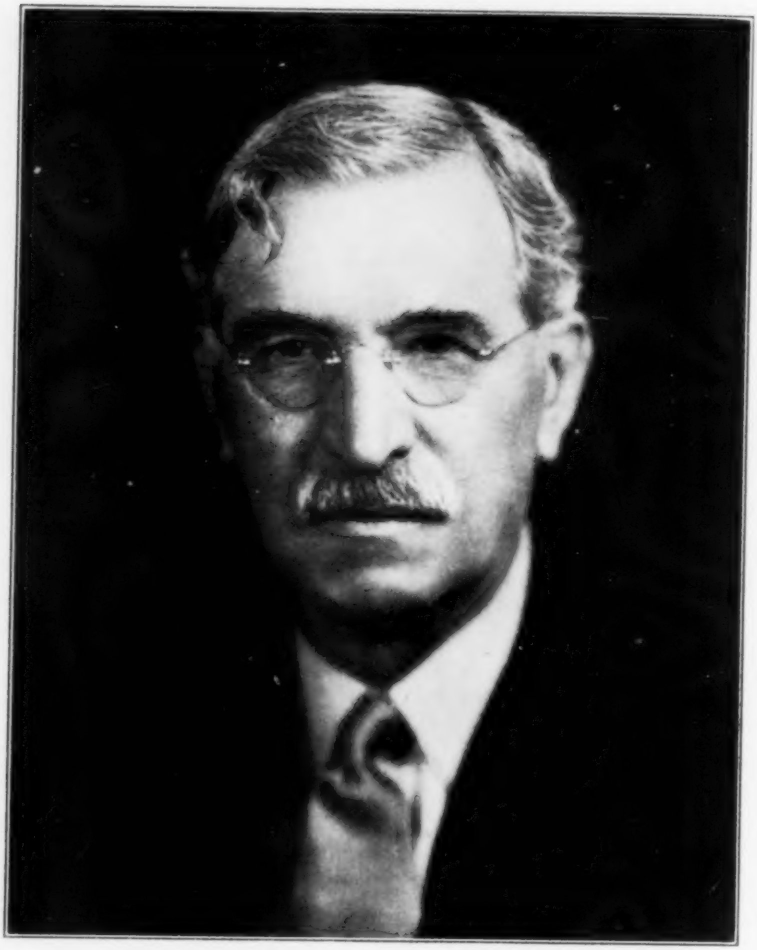
On March 27 at St. Petersburg, Florida, the members of the American Chemical Society held a meeting to discuss the chemistry of the latest addition to the chemical family of elements, the so-called "heavy hydrogen."

The search for this substance was begun about fifteen years ago, when Stern and Volmer and W. D. Harkins made unsuccessful attempts to find evidence for it. In 1930 Allison and his coworkers reported results in their studies with the magneto-optic method, which pointed very strongly to the presence in hydrogen compounds of an isotope of hydrogen with atomic weight two. At about the same time Birge and Menzel concluded from a study of atomic weights that such an isotope should exist.

In 1932 Urey, Brickwedde and Murphy provided final and indisputable proof of the isotope by concentrating it through the evaporation of liquid hydrogen. Thus it became apparent that a new and very important chapter of chemistry had begun.

The next important step was taken by E. W. Washburn, late chief chemist of the Bureau of Standards, working in collaboration with Professor Urey. They showed that a fairly rapid concentration of heavy hydrogen occurred when water was electrolyzed into hydrogen and oxygen.

This fact was then utilized by Dr. G. N. Lewis, of the University of California, through a series of electrolyses to bring about the first separation of a large amount of heavy hydrogen into something approaching the pure state. Following Lewis's demonstration that heavy hydrogen can thus be prepared, a large number of workers have made heavy hydrogen and are busy studying its chemical and physical properties.



DR. CHAS. L. REESE

Retired chemical director of E. I. du Pont de Nemours and Company, president of the American Chemical Society.

These historical facts were reviewed in the opening paper of the symposium by Professor Urey, who also described the work on heavy hydrogen now being carried on at Columbia University.

The second paper on the program was given by Dr. Brickwedde, director of the Cryogenic Laboratory of the Bureau of Standards, at which the discovery of heavy hydrogen was made in collaboration with Professor Urey. Following up the initial discovery, Dr. Brickwedde prepared pure heavy hydrogen in the liquid form and measured its boiling point and other important physical properties.

The third paper was given by Professor H. S. Taylor, of Princeton University, and described the work which has been carried on in the chemistry laboratory at that institution on various problems regarding heavy hydrogen. This laboratory was the first to put into operation a plant for the large scale manufacture of heavy hydrogen, and Professor Taylor and his co-workers have contributed many valuable ideas in connection with the theory and practice

PROFESSOR ROGER ADAMS

HEAD OF THE DEPARTMENT OF CHEMISTRY AT THE UNIVERSITY OF ILLINOIS, WHO HAS BEEN ELECTED PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY FOR 1935.

of separating the isotopes. They are particularly interested in the use of heavy hydrogen as a tool for investigating the nature and rate of chemical reactions.

It is particularly useful in this respect because it may be employed in reactions which have been studied extensively with ordinary hydrogen and the change to heavy hydrogen changes only the factor of mass, leaving everything else constant. The workers at Princeton have synthesized ammonia in which heavy hydrogen replaces ordinary hydrogen and find that the properties of this ammonia are quite different from those of the ordinary kind.

The fourth paper was given by Professor G. H. Dieke, of the department of physics of the Johns Hopkins University, and was a review of the spectroscopy of molecules containing heavy hydrogen. The introduction of heavy hydrogen into compounds such as ammonia and methane, one of the principal constituents of coal gas, gives these molecules the power to absorb light to which they are otherwise transparent.

The fifth paper was given by Professor Fred Allison, of the Alabama Polytechnic Institute. Professor Allison has developed an apparatus based on the magneto-optic effect, which enables the detection of very small amounts of the different chemical elements. He has applied this to the study of heavy hydrogen with extremely interesting results. In fact, he brought forward evidence for the existence of this substance some time before Professor Urey discovered that it was possible to concentrate it and thus prove its existence beyond any question of doubt. Allison has recently confirmed the results reported by Professor W. M. Latimer and Dr. Herbert A. Young, of the University of California, which indicate the possibility that a type of hydrogen exists in which the atom has the mass three.

The afternoon session of the meeting was devoted to papers of a more specialized nature, dealing with phases of the problem which have been studied recently. A paper by the late Dr. E. W. Washburn and Edgar R. Smith was read on the separation of heavy hydrogen by the vital processes in a growing willow tree.

Dr. Leigh C. Anderson, Dr. J. R. Bates and Dr. J. O. Halford, of the University of Michigan, have developed a means of preparing heavy hydrogen by the continuous flow of water through a long trough in which a number of electrodes are placed. They have used the heavy hydrogen so prepared for studying a number of organic chemical reactions.

Messrs. D. H. Rank and G. H. Fleming, of the Pennsylvania State College, have prepared a compound of carbon and heavy hydrogen, so-called neopentane, which shows the great effect produced on the spectrum of the compound by the substitution of heavy hydrogen for ordinary hydrogen. Professors D. Rittenberg and Urey at Columbia University have studied the reactions between iodine and heavy hydrogen with important theoretical results.

Dr. P. W. Selwood, of Princeton University, read a paper on the specific gravity of mixtures containing heavy hydrogen.

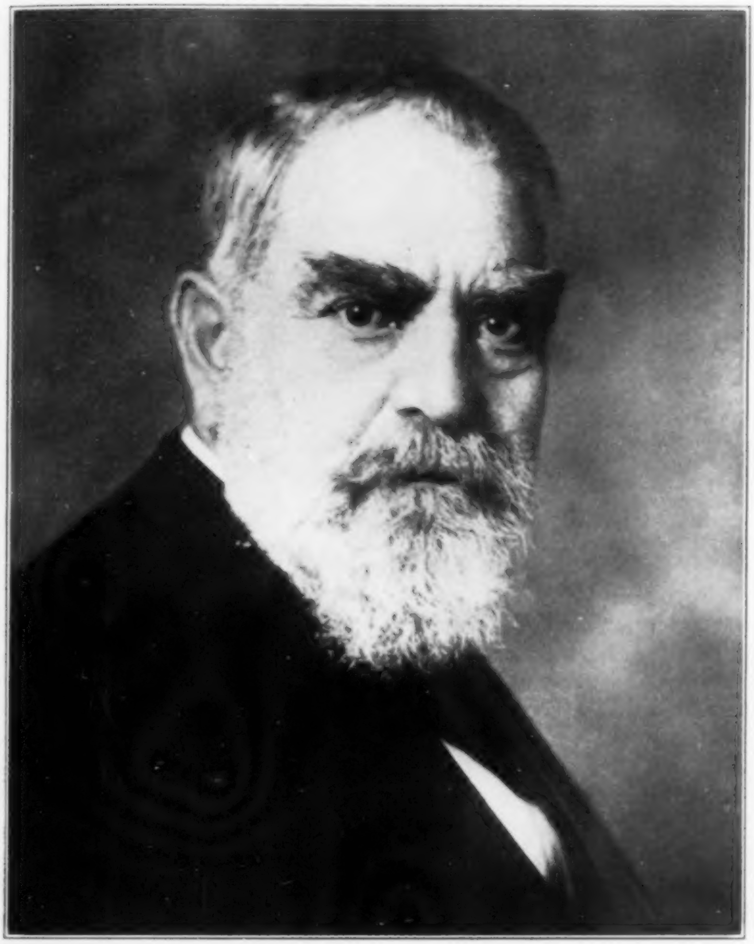
Professor N. F. Hall, T. O. Jones and E. Bowden, of the University of Wisconsin, reported that heavy hydrogen has a great tendency to exchange place with ordinary hydrogen in a number of materials. For this reason, if one has a compound containing heavy hydrogen great care must be exercised in placing it in contact with ordinary water or other compounds containing ordinary hydrogen.

Dr. B. Topley and Dr. H. Eyring, of Princeton University, read papers on the theoretical aspects of the subject. Dr. Topley found that the fact that heavy hydrogen will separate in electrolysis is due not to diffusion, but to certain differences between heavy and light hydrogen which affect the so-called quantum mechanics of the reaction.

Dr. Eyring's paper pointed out that the study of water containing heavy hydrogen gives important insight into the nature of this universally useful substance. It indicates that the water molecules can rotate freely in the liquid.

Besides the symposium on "heavy hydrogen" a number of other interesting papers were read before the meeting on topics of general chemical interest. Dr. M. T. Bogert gave an address entitled "Your Nose Knows," dealing with the chemistry of perfumes. Papers of interest to the industrial chemists were read by Dr. C. H. Herty on "Pine Products," E. L. Smith on "Chemical Securities," E. E. Ware on "The Trend in Protective Coatings" and W. H. Dow and L. C. Stewart on "The Commercial Extraction of Bromine from Sea Water." The pleasant surroundings at St. Petersburg, together with the beautiful Florida weather, made the meeting one of the most enjoyable which the society has held.

DONALD H. ANDREWS

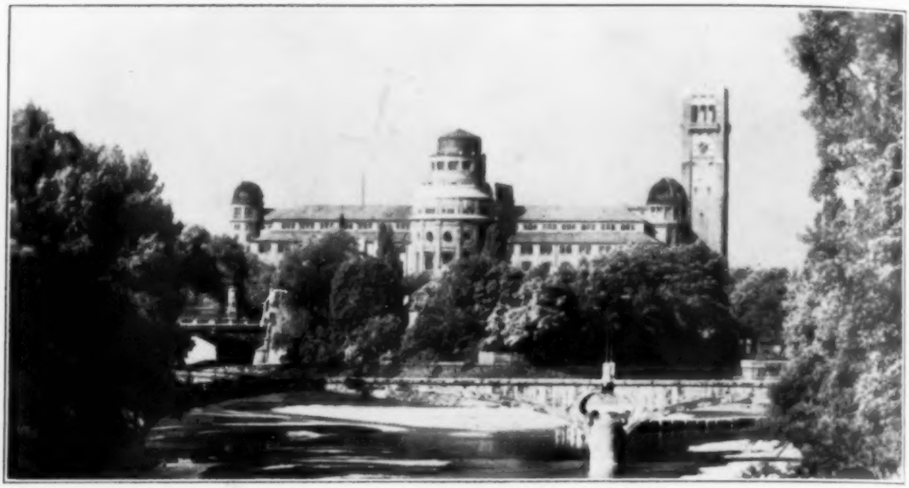


OSKAR VON MILLER

THE news that Dr. von Miller died in Munich on April 8 at the age of seventy-eight (he would have been seventy-nine on May 7) will be received with regret by scientists and engineers all over the world. Although he was known chiefly as the creator of the famous Deutsches Museum he had made an international reputation for himself as a pioneer in electrical engineering.

After graduating from the Polytechnikum of Munich von Miller entered the service of the Bavarian government. At the Paris Electrical Exposition of 1881, whither he went to broaden his technical knowledge, the sight of electric incandescent lamps and dynamos exhibited by Edison, of streets illuminated by arc lamps, of telephones, of motors that drove machines so overwhelmed him that on his return he organized the Munich Electrical Exposition of 1882, the first held in Germany. There he demonstrated the much-doubted feasibility of transmitting electric energy over an experimental line of telegraph wire stretched between Miesbach and Munich, a distance of 57 kilometers.

Joining Emil Rathenau in 1883 in founding the German Edison Company



THE DEUTSCHES MUSEUM

von Miller designed the first central station of Berlin and formally opened it on September 13, 1884. The company later became the Allgemeine Elektrizitätsgesellschaft. Although he could have remained with the organization he preferred to open his own offices in Munich. As the technical director of the Frankfurt Exposition of 1891 he boldly demonstrated the practicability of transmitting alternating current a distance of 180 kilometers at 25,000 volts between Lauffen and Frankfurt from a 300-horsepower hydraulic plant. His success created an international technical sensation and established his reputation. Thereafter he was much in demand as a consulting engineer in developing the water power of his native Bavaria and expanding the electrical network of the old empire. He must be numbered among the daring technical pioneers in practically applying electric energy.

It was in 1903 that von Miller laid before the representatives of German industry the plan of a museum which was not only to preserve the masterpieces of engineering and science, but to teach technology with the aid of sectioned models that could be thrown into operation by any visitor merely by pushing a button or pulling a lever. The proposal was received with acclamation. In a year the now famous Deutsches Museum of Munich was actually in existence, housed in the abandoned National Museum. In the new building, which was erected on an island in the Isar and which was ceremoniously opened in 1925, some 60,000 objects of scientific and technical interest are displayed. Over a million visitors annually walk about ten miles through these exhibits, operating those that have moving parts and studying the dioramas and paintings. To this imposing structure von Miller added a *Studienbau* or technical library, with lecture halls.

Although the Conservatoire des Arts et Métiers of Paris and the Science Museum of South Kensington are both older than the Deutsches Museum there can be no doubt that von Miller revolutionized museum practise. So far as he could he abandoned glass cases. Attendants were to be not watchdogs but aids. The visitor was to handle and operate anything within reason, and if this was impracticable, as in the case of a locomotive, he was to summon a trained guard to assist him. Instead of a storehouse of historic relics the Deutsches

Museum is an institution where the rudiments of science and technology may be acquired by any intelligent visitor. The lesson was so dramatically effective that older technical museums soon followed von Miller, and American philanthropists were inspired to lay plans for similar dynamic technical museums in Chicago, New York and Philadelphia.

WALDEMAR KAEMPFFERT

HAZARDS TO AIRCRAFT DUE TO ELECTRICAL PHENOMENA

NUMEROUS suggestions, including various fanciful ideas, have been presented in press notices or otherwise, to explain by means of great electrical forces the destruction or injury which has occurred from time to time of huge airships and other types of aircraft exposed to thunderstorm conditions. In order to secure a fair appraisal by experts of the merits of such suggestions and to ascertain if further investigations were advisable, the National Advisory Committee for Aeronautics, upon the request of one of the federal agencies responsible for the operation of airships, appointed a special committee to consider and report upon the general question of hazards to aircraft, both airships and airplanes, due to electrical phenomena.

This committee was composed of the following members: Dr. L. J. Briggs, Bureau of Standards; Commander Garland Fulton (C. C.) U. S. N.; Dr. W. J. Humphreys, Weather Bureau; Dr. J. C. Hunsaker, Massachusetts Institute of Technology; Dr. F. B. Silsbee, Bureau of Standards; Professor John B. Whitehead, The Johns Hopkins University; Mr. G. W. Lewis, National Advisory Committee for Aeronautics (*ex-officio*), and Dr. Charles F. Marvin, U. S. Weather Bureau, *chairman*.

The committee profited in its study of the problem by the assistance of Dr. M. F. Peters, of the Bureau of Standards, and was also guided by a prior confidential report on the same question by a British authority and by reports of recent German investigations. It is believed confidence is justified in the unanimous conclusions of the committee, herein briefly presented under two types of electrical influence.

ELECTROSTATIC ATTRACTION OF AIRSHIP TO EARTH

Alleged estimates of the magnitude of such forces by various authors differ from a few ounces to many tons. Large airships consist of a huge cage of closely bonded metallic and electrical conducting framework, with thin fabric or metal covering and numerous fabric gas cells enclosed in more or less closely meshed wire netting. When floating in the atmospheric electric field between the earth and the clouds, the ordinary processes of electrostatic inductions tend to separate the positive and negative electrical charges on such an object, and if, for example, the negative charges were partially or wholly dissipated, the structure would tend to be drawn down to the earth below by the electrical attraction.

Dr. Simpson, of the British Meteorological Office, from a careful analysis of the probable magnitude of this attraction on a large airship, places it at a *few hundred pounds*. Even assuming that in extreme cases the atmospheric field might be of higher intensity than used in Dr. Simpson's calculations, our committee was convinced that the forces due to electrical attractions between an airship and the ground can not rise to dangerous values.

The possibility of the accumulation of high values of electrostatic charge due to the fall of positively charged rain was also reviewed. A high positive charge on the ship by falling rain is possible, of course, only provided little or none of the accumulated charge escapes. The continuous escape of such charges is, however, greatly facilitated by several causes. In the first place, after a short

time as much rain must fall away from the airship, carrying off its charge, as falls upon it. Many exposed metallic points of short radius of curvature all over an airship tend to dissipate any great accumulation of electrical charge. Finally, the highly ionized condition of the exhaust gases from the engines of airships in flight also dissipate electrical charges.

It was concluded that the maximum possible attractive forces due to rain or other sources of electrification were about of the same order of magnitude as in the case of those possible by ordinary electrostatic induction.

That airships in flight do become somewhat highly electrified is shown by the cases of shock to men grasping mooring ropes. The actual magnitude of such charges is shown to be moderate because no such shocks have been fatal.

All these considerations seem conclusively to indicate that the forces of electrical attraction between aircraft and the earth can not attain sufficient magnitude to be hazardous in themselves.

High-Frequency or Steep-Wave-Front Lightning Discharges

A possible type of electrical hazard may arise from the existence in proximity of an airship of very high frequency electrical discharges, and while actual lightning strokes are not strictly high frequency discharges in this sense, nevertheless it is pointed out that the very steep wave front which may characterize the tumultuous rush of a violent stroke of lightning may itself be the origin of effects resembling those due to true high frequency discharges. The hazards due to electrical influences of this character arise from relatively small secondary sparks which may possibly occur within the structure of the aircraft itself and may puncture gas bags or possibly ignite inflammable gases or other material.

A high degree of internal protection from the hazards is automatically provided by the bonded metal framework of either an airplane or an airship. This protection is based upon the well-known electrical principle of the Faraday cage and is more effectual in an all-metal airplane than one in which wood and fabric are used. In the airship the protection is greater the closer the meshes of the metallic framework and the wire bracing, and the smaller the mesh of the wire netting enclosing the gas bag. Further protection is assured whenever the surface of the outer envelope is a good electrical conductor. While it is possible for a direct lightning stroke to damage an airship by passing between meshes of the framework, past experience affords no evidence of the occurrence of such phenomena, and grave doubt that it occurs as a dangerous hazard is justified. Furthermore, the committee does not find sufficient evidence of the existence of disturbances of this character to warrant a program of experimental study.

In this connection, it is known that trailing radio antenna and cables used in suspending observers may facilitate direct lightning strokes. However, protection from such hazards is afforded during thunderstorm conditions by reeling in the observer's cable and antenna or the use of other types of antenna.

Storm Areas Should be Avoided

When proper precautions are taken, and when the customary protective methods inherent in bonded metallic cage construction are utilized, the committee considers the probability small that serious damage from electrical charges and discharges will result. But even though neither airplanes nor airships are in much danger from lightning, both must make every effort to avoid thunderstorms—must keep out of the exceedingly violent and extremely turbulent winds of thunderstorms which cause great danger of destruction.[1]

Charles F. Marvin

[1] The report in full is being published as a Technical Note by the National Advisory Committee for Aeronautics.